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~~War 19.30~~
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Lieut. W. Robinson

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Captain James M. Ingalls, 1st U. S. Artillery,
Lieutenant Erasmus M. Weaver, 2nd U. S. Artillery,
Lieutenant George O. Squier, 3rd U. S. Artillery.
Lieutenant Edgar Russel, 5th U. S. Artillery.

EDITOR.

Lieutenant John P. Wisser, 1st U. S. Artillery.

ASSISTANT EDITOR.

Lieutenant Andrew Hero, Jr., 4th U. S. Artillery.

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JOURNAL

OF THE

UNITED STATES ARTILLERY.

VOL. VII. No. 1. JANUARY—FEBRUARY, 1897. WHOLE No. 24.

AN EXPERIMENT WITH MILITIA IN HEAVY ARTILLERY WORK.

During the past year the officers of the Second Artillery at Fort Warren and those of the First Regiment of Infantry of the Massachusetts Volunteer Militia have been engaged in a most interesting experiment.

Appreciating on both sides the desirability of having a body of Reserves which might in case of emergency re-inforce the regular troops at Fort Warren, we have worked together to see what might be done toward training militiamen in heavy artillery. The officers and men of the First Regiment of Infantry having been assigned by General Samuel Dalton, Adjutant General of Massachusetts, to heavy artillery duties, and the commanding officer of Fort Warren, Lieutenant-Colonel Carle A. Woodruff, 2nd Artillery, having been requested by General Dalton to assist the regiment in its work, the militia, officers and men, threw themselves willingly and earnestly into the work, and, we, on our part, have done what we could with the armament and means at hand to give them instruction.

It is thought that some account of what has been done might be of interest to others, and, as it fell to my lot to do a considerable share of the instruction and direction of the work I will venture to give some account of it, making use, as far as possible, of the orders and correspondence connected therewith.

About the middle of January, 1896, General Dalton interviewed
onel Woodruff in regard to having the regular officers at Fort
ren give instruction to the militia. Colonel Woodruff on his
part, and on the part of the officers of the garrison, readily
nted, and it was arranged that the instruction should begin
ice. In consequence of this decision the following order was
d initiating the movement.

COMMONWEALTH OF MASSACHUSETTS.
ADJUTANT GENERAL'S OFFICE.

GENERAL ORDERS, No. 3. Boston, January 23, 1896.

Lieutenant-Colonel Carle A. Woodruff, commandant at Fort Warren, having, with his officers, kindly volunteered to instruct the First Infantry in heavy artillery and light artillery, schools have been arranged as follows:

Evenings of January 27, February 24, March 11, March 31. The commissioned officers of the First Regiment of Infantry will assemble at the Irvington Street Armory on the above evenings, at 8 o'clock, p.m., in undress uniform, without swords, for instruction.

The following will be the line of study:

1. The duties, organization, equipment and instruction of coast artillery.

2. The elementary instruction of the recruit.—(*a*) Physical training. (*b*) Artillery training. (*c*) Classification of "gunners."

3. Instruction of "gunners." - (*a*) Guns and mortars and their service. (*b*) Powders; taking powder pressures; magazine service. (*c*) Projectiles and their service. (*d*) Fuzes and their setting. (*e*) The motion and effects of projectiles. (*f*) Effect of density of air and winds on the flight of projectiles; use of the barometer, psychrometer and anemometer. (*g*) Cordage. (*h*) Mechanical maneuvers. (*i*) Flag signaling. (*j*) The azimuth circle and its use. (*k*) Shot plotting and ship tracking. (*l*) Range tables and their use. (*m*) Sights and their setting. (*n*) Laying guns on fixed objects. (*o*) Laying guns on moving objects. (*p*) Laying guns and mortars by the indirect method. (*q*) Estimation of distances. (*r*) Simulated target practice at fixed and moving targets. (*s*) Target practice with shot.

4. Instruction of the battery. - (*a* Formation and posting at the guns. (*b*] Service of the battery. [*c*] Alarm drill. [*d*] Combat drill.

In so far as possible the above course will be of a practical nature; much of it can be carried out in the armories; what cannot be done in the armories will be practiced at Fort Warren, when provision is made for the same.

Lieutenant E. M. Weaver, United States Army, has been designated by Colonel Woodruff as the instructor in heavy artillery, and all officers will give him every attention and facility in his work.

Lieutenant Weaver has offered to visit companies drill evenings and give instruction to companies and to the company officers.

The program embraces any emergency duty at Fort Warren, and the course of study during the winter will be practically carried out during the summer at the Fort.

* * * * * * *

By order of the COMMANDER-IN-CHIEF,
[Signed] SAMUEL DALTON,
Adjutant General.

Four lectures were given covering the subjects enumerated in the above order. When possible the lectures were illustrated by using instrument, implements, etc., and by having the officers of the militia personally perform the operations. In shot plotting and ship tracking a reduced field of fire was laid out on the armory floor and by using a reduced base line, and having a miniature ship, reduced also to the same scale, moved over the field of fire, it was possible to do everything connected with firing in the armory except fire the gun. Dummy 8-inch converted rifles of full size behind parapets at one end of the armory permitted a gun detachment to point and fire—using only friction primers—at the reduced target. Estimating distances and setting sights were also practiced according to the same principles that would be employed with real guns over an actual field of fire. Both the direct and indirect method of firing were thus illustrated, and under the latter method it became apparent that it would be possible to attribute to the shot a theoretical flight and plot a hypothetical "splash" determined by the setting of the rear sight for range and the reading of the azimuth scale for direction.

Thus it appeared that all the essential elements of target practice could be carried out within the limits of a large armory such as that of the First Regiment.

Ship tracking was readily illustrated. The positions of the miniature ship were plotted at half-minute intervals and the dummy gun laid accordingly. In this work and in the lecture on cordage I had the assistance of several non-commissioned officers from Batteries C and M, 2d Artillery.

In connection with this instruction a series of drills and exercises was drawn up, adapted to the limited time available for drills, and having in view the week's tour of duty in August. These exercises were taken up by the regiment about March 1, and formed the basis of the drill work of all companies up to the encampment.

Under the Fourth Exercise an Alarm and Combat Drill was arranged similar to that used at Fort Warren; a copy of this is given in Circular 2 from Headquarters First Regiment, dated July 25. 1896, which follows below. Special Order No. 24, from the Adjutant General's Office Massachusetts gives the drill exercises as follows:

COMMONWEALTH OF MASSACHUSETTS.
ADJUTANT GENERAL'S OFFICE.

SPECIAL ORDERS, No. 24. BOSTON, February 21, 1896.

By direction of Lieutenant-Colonel Carle A. Woodruff, United States Army' Lieutenant E. M. Weaver has submitted a schedule of drills for the First Regiment of Infantry, M. V. M., in heavy artillery.

Careful instruction in the above exercises will be given by officers to non-commissioned officers and privates. These exercises will form the basis of the drill program to be carried out at Fort Warren during the next encampment, as indicated in connection with the heading of each exercise. Officers will be expected to take charge of and carry out the requirements of any sub-heading, under any exercise, which may be assigned to them.

(Numbers in parenthesis indicate paragraphs in Tidball's Manual, edition of 1880.)

FIRST EXERCISE.

1.—March the battery to the guns (106-107). 2.—Post the cannoneers at the guns (108). 3.—Take equipments (109) (278 for 10-in. S.B. gun) (295 for 15-in. S.B. gun) (310 for 8-in. M.L. rifle). 4.—Change posts (112). 5.—Service of the guns (276 to 286 for 10-in. S.B. gun) (294 to 308 for the 15-in. S.B. gun) (321 to 340 for the 8-in. M.L. rifle). 6.—General rules (230).

SECOND EXERCISE.

1.—Cordage, pulleys, blocks and tackle (476 to 484). 2.—The service of the gins (486, siege gin, to 495, garrison and casemate gin). 3.—The use of the sling cart (502-503). 4.—The hydraulic jack and its use in mechanical maneuvers (522 to 529). 5.—Blocks, skids, etc., used in mechanical maneuvers (528 to 532).

THIRD EXERCISE.

1.—Post the detachment for mechanical maneuvers (415). 2.—Dismount barbette gun with with the gin (497) (498) (499). 3.—Mount barbette gun with the gin (499) (498) (497). 4.—Dismount barbette guns by means of blocks, etc., (542) (543) (544). 5.—Mount barbette gun by means of blocks, etc., (544) (543) (542).

FOURTH EXERCISE.

Combat drill as heretofore forwarded to the commanding officer of First Infantry.

FIFTH EXERCISE.

Will take place at Fort Warren and will consist of firings with projectiles.

Requisition may be made for such appliances as are necessary to carry out this order.

By order of the COMMANDER-IN-CHIEF,
(Signed) SAMUEL DALTON,
Adjutant General.

HEADQUARTERS FIRST REGIMENT INFANTRY,

FIRST BRIGADE, M. V. M.

CIRCULAR }
No. 2. }
SOUTH ARMORY, BOSTON, July 25, 1896.

COMBAT DRILL.

The drill will take place at such time as the Commanding Officer may prescribe. At the sound of the "Alarm," all officers and enlisted men will immediately run to the positions prescribed and await orders. Instructions for cannoneers will be those prescribed in the Heavy Artillery Drill Manual.

ORGANIZATION.

Captain in command of Battery.

First Sergeant	with Captain.
Musician	" "
Private	" "
"	" "
"	" "

FOR SERVICE OF GUNS.

First Lieutenant in charge of Gun Battery, Chief of the First Platoon.

Sergeant	Chief of 1st Detachment		1st Gun.
Corporal	Gunner " "		" "
Private	Cannoneer No.	1	" "
"	"	2	" "
"	"	3	" "
"	"	4	" "
"	"	5	" "
"	"	6	" "
"	"	7	" "
"	"	8	" "
"	"	9	" "
"	"	10	" "
Sergeant	Chief of 2d Detachment		2d Gun.
Corporal	Gunner " "		" "
Private	Cannoneer No.	1	" "
"	"	2	" "
"	"	3	" "
"	"	4	" "
"	"	5	" "
"	"	6	" "
"	"	7	" "
"	"	8	" "
"	"	9	" "
"	"	10	" "

FOR SUPPLY OF AMMUNITION.

Second Lieutenant in charge of supply and Chief of Second Platoon.

Sergeant	Chief of Powder Detachment.
"	Chief of Projectile Detachment.
Corporal	Powder Corporal, *in Service Magazine.*
Corporal	Projectile Corporal, *at main projectile supply.*
Private	Service Magazine Assistant.
"	Powder Carrier No. 1,
"	" " 2,

for 1st Gun.

Private	Powder Carrier No. 3,
"	" " 4,

for 2d Gun.

Private	Powder Carrier No. 5,
"	" " 6,

between main and service magazine with hand cart. Carry 4 charges at time.

Private	Projectile Carrier No. 1,
"	" " 2,
"	" " 3,
"	" " 4,

from main supply to 1st Gun.

~~War 19.30~~
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July.—Review of Exercises Nos. 1, 2, and 3.—Instruction of gunners in simulated firing continued and flag signaling continued.

August.—Examination of gunners by regimental board.—Encampment at Fort Warren during which the above course will be put into application.

As to the "gunners" it was the idea that the class in each company would be made up of men who would volunteer to give extra time to the study and practice of these subjects included in the gunners course.

Each company of the regiment had two drills a week throughout the year.

That this preliminary armory course was beneficial was evident by the manner in which most of the companies took up the work at Fort Warren. The encampment gave an excellent opportunity to test what had been done, and those companies which had faithfully pursued the armory course were in far better positions at the outset than the few which had not done so.

The practical work during the encampment was performed in accordance with the following schedule, which was prepared sometime before the encampment began and placed in the hands of captains about a month before, in order that each might know definitely what his company was to do during the entire week of the tour of duty.

HEADQUARTERS FIRST REGIMENT OF INFANTRY.
FIRST BRIGADE, M. V. M.

CIRCULAR }
No. 1. }
SOUTH ARMORY, BOSTON, July 9, 1896.

The following schedule of drills having been arranged by Lieutenant-Colonel Carle A. Woodruff' Commandant at Fort Warren, for the coming tou of duty of this command, will be strictly followed by officers and enlisted men

1. Batteries will form on battery streets five mimutes before the schedul hour for drill and be marched at once to the place appointed for the drill.

2. Instructors will so conduct drills as to leave pieces, materials and equip ments in proper position, condition and form for the succeeding battery t begin the drill.

3. The instructor in charge of drill during the fifth period, each day, wil make all things secure for the night at the end of the drill.

4. The drills at the guns (8-inch rifle, 10-inch and 15-inch smooth bore) wi include the following:—

(1) Description of the piece, carriage and ammunition, and nomenclatu of parts of the piece and carriage. (2) Post cannoneers at the piec (3) Change posts of cannoneers. (4) Service of the piece. (5) March fro battery.

5. Drill in cordage will include the following:—

(1) Make the square knot; the bowline knot; round turn and half hitch timber hitch; blackwall hitch; catspaw; sheepshank. (2) Worm and serve piece of rope; whip the end of a rope; make a short splice; a long splic

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eye splice; grommet; strap. (3) Apply stop lashing; nipper lashing; a screw; seizing; a mousing; a shear lashing. (4) Sling a barrel on end; on side. (5) Reeve a gun tackle purchase; luff tackle; runner tackle; a single Burton; a whip on whip.

The battery will be divided into gun detachments and each detachment will be instructed by its non-commissioned officers under the supervision of the battery officers.

6. The drill in mechanical maneuvers will include the dismounting of a 10-inch gun on barbette carriage by means of blocks and remounting it; also the dismounting and remounting of a 10-inch barbette gun by means of the gin.

7. In case the battery is not able to complete this drill in its drill period, the following battery will take up the drill at the point arrived at and carry it on from that point.

8. The drill in the use of mechanical appliances will include the following:

First Detachment.—Service of the siege gin; assemble the gin: reeve the fall; raise the gin; move the gin; dismount a siege gun; mount a siege gun (see paragraphs 486 to 491, Tidball's Manual); lower the gin; take the gin apart.

Second Detachment.—Use of sling cart; sling siege mortar mounted on its carriage and transport it; sling sea-coast mortar on garrison sling-cart.

Third and Fourth Detachment.—Use of capstan and hydraulic jack; place 15-inch gun on cradle and transport it.

9. Magazine instruction will include the preparation of cartridges and projectiles for the guns.

10. Target practice will include five rounds of solid shot from the 8-inch rifle, as follows:—

1. Three rounds at fixed target at 3,600 yards range. 2. Two rounds at moving target.

11. Field officers will inspect daily the work of the batteries of their respective battalions. They will report to the Colonel in writing at the close of each day the result of the day's work. In making this report each field officer will state the manner in which each battery has performed the work assigned to it, mentioning in detail, in a special way, any particularly meritorious work, and likewise mentioning any failure to attain a proper degree of proficiency or any exhibition of lack of application.

By order of COLONEL MATHEWS.

OFFICIAL:

The program was carried out in all its parts. With the exception of some delay in target practice by reason of most unfavorable misty and foggy weather making it impossible to see the target for the greater part of two days, there was no departure from the strict letter of the program.

My report to the Adjutant General of Massachusetts, which is given below, sets forth the excellent manner in which the work was performed. It was really quite surprising to note how promptly each drill was taken up and how much interest and energy was manifested by officers and men. As an evidence of the skill attained, it may be mentioned that the 10-inch gun was dismounted and mounted four times by means of blocks, and using the gin and the Mills hitch, the gun was generally dismounted and mounted within fifteen minutes, starting with the blocks and fall on the ground, and the gun in battery.

In the combat drill on Friday afternoon all the guns on the east front of the fort were manned by the militia and the regular troops of the garrison. Twelve guns being assigned to the militia—four to each battalion—and two to the regulars. In the morning the majors in command of battalions had instructed the captains as to the particular guns their companies would serve and the captains had assigned individuals to their respective duties. The "alarm" sounded when the men were scattered promiscuously about the post. Powder was served from the magazines for three rounds from each gun. The guns were loaded and fired three times within six minutes from the first note of the "alarm," and within ten minutes the batteries had left the guns, had been marched off and dismissed.

The target practice was creditable considering the unfavorable weather conditions. The target was at about 3000 yards range. The mean absolute deviations were as follows:

FIRST MASSACHUSETTS (V.M.) INFANTRY.

RETURN OF TARGET PRACTICE.

Fort Warren, Boston Harbor, August 4-8, 1896.—8-inch M.L.R.; service charge and projectile.

Battery.	Average Distance Target. Yards.	Average Distance Splash. Yards.	Mean Average Deviation.	Hits on Vertical Plane.
*A	—	—	—	—
B	3060	2778	101	3
C	3620	3628	93	1
D	3612	3381	224	—
E	3322	3295	27	1
F	3635	3663	63	—
G	3318	3295	25	3
H	3625	3941	413	—
I	3267	3072	200	1
K	3231	3192	57	2
L	3325	3250	107	—
M	3348	3378	80	:

* No report on file.

(Signed) CHARLES L. HOVEY,
Lt-Col., 1st Mass. Infantry.

Official copy:

(Signed) JAMES A. FRYE,
Lieutenant and Adjutant,
1st Mass. (V.M.) Infantry.

The daily list of calls during the encampment is given below:

HEADQUARTERS FIRST REGIMENT INFANTRY, M. V. M.
CAMP AT FORT WARREN,

GENERAL ORDERS, }
No. 17. }
BOSTON HARBOR, August 1, 1896.

The routine of duty below noted will be followed by the command during the tour at Fort Warren, August 1st to 8th, 1896:

First Call,	5:50	A. M.
Reveille, Roll-Call and Setting-up Drill,	6:00	"
Fatigue Call, Police entire Camp,	6:15	"
Breakfast Call,	6:30	"
Surgeon's Call,	7:00	"
Officers' Call,	7:10	"
First Sergeant's Call,	7:15	"
Drill Call, Commencement of Morning Schedule	7:30	"
First Call, Guard Mounting,	8:40	"
Adjutant's Call, Guard Mounting,	9:00	"
Inspection Quarters,	9:30	"
Recall, End of Morning Schedule,	12:00	M.
Dinner Call,	12:30	P. M.
Drill Call, Commencement of Afternoon Schedule,	2:00	"
Recall, End of Afternoon Schedule,	5:00	"
First Call, Evening Parade,	5:30	"
Assembly, Evening Parade,	5:40	"
Adjutant's Call, Evening Parade,	5:45	"
Supper Call,	6:30	"
Tattoo Roll-Call,	9:00	"
Call to Quarters,	10:45	"
Taps,	11:00	"

By order of COLONEL MATHEWS.
(Signed) JAMES A. FRYE,
1st Lieutenant and Adjutant.

The experiment has impressed me with the practicability of developing along the entire sea-board corps of Coast Defence Reserves, bodies that would be permanently associated with the defense of adjacent coast lines and stand back of the regular heavy artillery troops ready to reinforce the latter immediately on the outbreak of war.

By associating ourselves intimately with the citizen soldiery in this way we would have the opportunity of serving each year for a period of a week or ten days with numbers of men and under conditions closely approximating to those of war time.

Furthermore, it will do the artillery no harm to have itself closely allied in work, feelings and interests with so great a body of voters. One of our great difficulties has seemed to be that our interests have been of special consequence to no one else, and without a chief in Washington to speak for us and without votes to bear upon congressmen we have practically been out of court.

But, apart from these considerations, we can never hope to have a small fractional part of the 80,000 artillerymen estimated as necessary for completely manning the guns of the proposed system of defence, and the safety of the country therefore demands that a reserve of some form be created.

If congress will give us the legislation proposed by Colonel the Honorable William Cary Sanger, Assistant Chief of Artillery of New York, in No. 18 of this *Journal* for January-February, 1896, the question of reserves would be well solved. But, while awaiting so complete a solution, may we not induce some of the great seaboard states to corps of Coast Defence Reserves in the same way as they have created the Naval Reserves? With such corps in existance we shall be in better position to work for further advance, and shall have the identity of interests of the new corps with ours to help us.

Ever, and throughout all efforts at organization, whether they pertain to the regular artillery or to such reserves as may be created, we should keep closely in view the controlling, salient fact, that coast defence is a distinct division of work, differentiated from that of the line of the army, and that the personnel assigned to this work should have an organization divorced in every respect from permanent connections with regiments, brigades and army corps, while always ready to serve on riot or other emergency duty (temporarily) away from the forts and big guns.

In this connection I venture to accompany this account of the heavy artillery work of the First Regiment of Infantry Massachusetts Volunteer Militia with a suggestion made to the Adjutant General of the state as to the organization of a corps of Coast Defence Reserves for the state of Massachussetts.

Copy of report made to Major General Samuel Dalton, M.V.M. on the tour of duty of the First Regiment of Infantry M. V. M. in heavy artillery work at Fort Warren, Mass., August 1, to August 8, 1896.

FORT WARREN, MASS.,

August 31, 1896.

Major General Samuel Dalton, Adjutant General Massachusetts Volunteer Militia, Boston, Mass.

(Through Major Carle A. Woodruff, Commanding Officer Fort Warren, Mass.)

Sir :—

Referring to my recent connection with the First Regiment of Infantry, M. V. M., in heavy artillery work, it has seemed fitting that I should offer a few comments on the work done by the regiment, and suggestions as to how that which has been acquired may not be lost, but made to serve as a stepping stone to a higher standard of coast defence work and have perhaps a far reaching effect under your guidance in providing a *Coast Defence Reserve* force for the entire sea-coast line of the country.

Major Woodruff, having detailed me to assist you in the heavy artillery instruction, I submitted for your consideration a theoretical and practical course of *armory instruction* arranged with regard to the week's tour of duty at Fort Warren, August 1, to August 8, 1896. These preliminary courses were published from your office in General Orders No. 3, dated January 23, 1896, and Special Orders No. 24, dated February 21, 1896.

The work laid out in these orders was performed in a satisfactory manner by the regiment. The regiment threw itself earnestly, and, in some cases, enthusiastically, into the work.

Battery "C" (Nutter's), Battery "D" (Frothingham's) and Battery "L" (Whiting's) went so far in the interest they took and in the energy thrown into the work that each, of its own volition, and at its own expense, passed a day at Fort Warren working at the guns, giving up the pleasures and attractions of a holiday for this purpose.

Other batteries made engagements with our non-commissioned officers to come to the city from time to time to give instructions to their non-commissioned officers.

In addition, the non-commissioned officers and privates of some of the batteries came to the fort in small squads during May, June and July for instruction.

I have had the pleasure also, of having had a number of the officers come to me at Fort Warren for advice and information in regard to the work they were doing.

The theoretical instruction given to the regiment on my part, was imparted in five lectures, in which I covered in an outline way, the headings given in General Orders No. 3, above referred to. The officers exhibited much interest in the subjects treated of, and, as was to be expected, were quick to take in and make use of the information given.

I wish to testify to all this and to the agreeable surprise it gave me to find citizens ready and able to take up and handle intelligently the details of coast defense artillery work.

As a consequence of this honest preliminary work in the armory, the regiment was made receptive for the work at Fort Warren during the first week of August. It is almost needless for me to express the very great satisfaction and pleasure it gave me, and, I may say, all officers of the post, to see the regiment take up the duties laid down in the schedule of drill prepared for the week without delay, hesitation or doubt.

The work throughout was done better than I expected it would be; and, I believe all, even the officers and men of the regiment themselves, were surprised at what could be done with so little preparation.

This leads me to say, that if this regiment could be kept permanently on this duty, or, better still, if these men could be organized into a separate corps, and assigned to all duties connected with coast defence, it would be possible in a short time to train them to the highest possible standard.

I wish to say quite positively that I have been strongly impressed with two features prominent in this experiment, namely :

1. It is possible to obtain a body of citizen soldiers, who can find a deep interest in the scientific work and practical mechanical work connected with heavy artillery.
2. That it is possible to train such men in a comparatively short time to be fairly efficient heavy artillerymen.

These conclusions seem to me to open a most important question; one which is of special importance to a seaboard state like Massachusetts.

It is of course, well understood that in case of foreign war with any maritime nation, Massachusetts would be exposed, at the very outset, to naval attack along her coast line. However well trained and disciplined, and however great the numbers of her militia might be, the infantry, cavalry and light artillery would be of no more use in defence against bombardment from the sea than the unorganized mass of human beings which surges up and down Washington Street daily.

Bombardment being an accepted war means of coercing an enemy—a means employed by England during the past week against defenceless Zanzibar—is it not, really, of more importance that Massachusetts, and especially Boston, should be provided with defence against this form of attack than, say, against invasion of our country by way of Canada?

The general government has made provision for erecting forifications and for placing therein an armament, which if properly manned by trained artillerymen, will render the whole coast line absolutely secure against naval attack; but the congress of the United States has not made, and probably will not make provision for an adequate personnel of United States artillerymen to man this armament.

The regular artillery is barely sufficient now to keep the various features of the fort's armament in condition to be used and to furnish instructors to the militia. The question arises, ought not the Commonwealth to organize a *Coast Defence Reserve*, a force that could be thrown into the forts of the harbor at the outbreak of war, re-enforcing the regular troops?

A *Corps of Coast Defence Reserves*, organized for this purpose trained in time of peace to serve the armaments of the forts in the harbor, instructed by the regular officers and non-commissioned officers, serving for a week or ten days each year at the forts side by side with the regular troops, as was done at Fort Warren during the first week of August, would give a body of troops of first importance, ready at all times for any emergency, whether it come from sea or from land, for such a corps would, of course, be trained in infantry battalion and company drill, for riot or other emergency land service, in addition to its primary drill and instruction connected with coast defence.

It would give Massachusetts, certainly, an efficient body of coast defence troops, and would make the commonwealth the pioneer in this branch of defence as she was in organizing the naval reserves.

I would ask, therefore, that you give the accompanying "*Suggestion for the reorganization of the First Regiment of Infantry M. V. M. and for the organization of a corps of coast defence reserves, M. V. M.*, your careful consideration; and, if it meet your approval, the support of your department.

Very respectfully,
(Signed) E. M. Weaver,
First Lieutenant, 2nd Artillery.

Colonel Woodruff, in forwarding the above to General Dalton, placed the following endorsement thereon:

First Endorsement.

FORT WARREN, MASS.,

September 1, 1896.

Respectfully forwarded to Major General Samuel Dalton, Adjutant General, Massachusetts.

I concur in all that is contained in the papers within.

The time is now ripe for something to be done in the matter of coast defence. The regular army may never be sufficiently large to more than care for the elaborate guns and emplacements proposed and being constructed and it will necessarily become the duty of the states to assist in the protection of their seaboard.

(Signed) CARLE A. WOODRUFF,
Major and Brevet Lieutenant-Colonel,
Commanding Post.
E. M. WEAVER,
First Lieutenant, 2d Artillery.

(To be concluded.)

◆

NOTES ON EUROPEAN SEA-COAST FORTIFICATIONS.

Translated and compiled from the French: *La Défense des Côtes d'Europe, par Carl Didelot.*

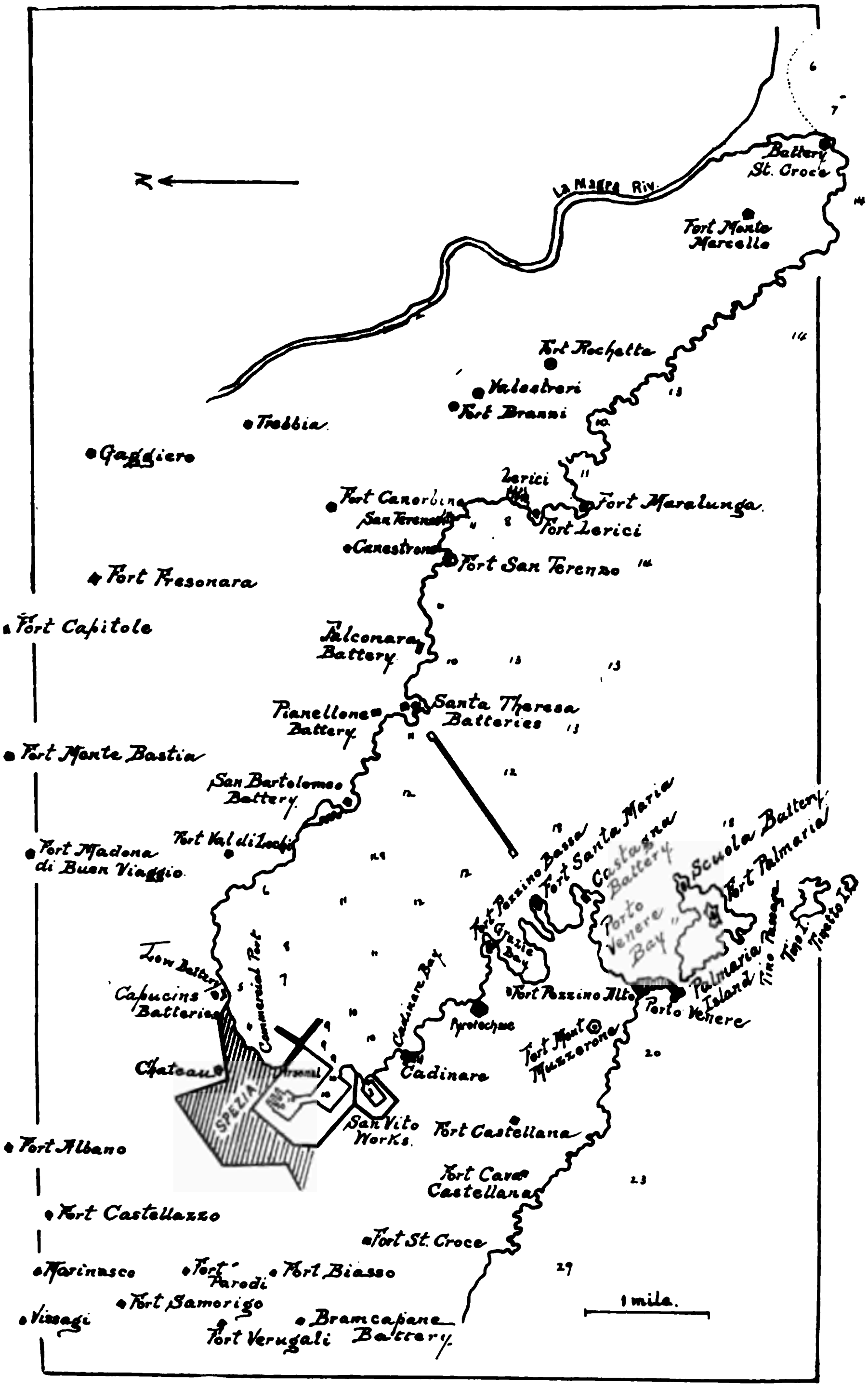
ITALY.

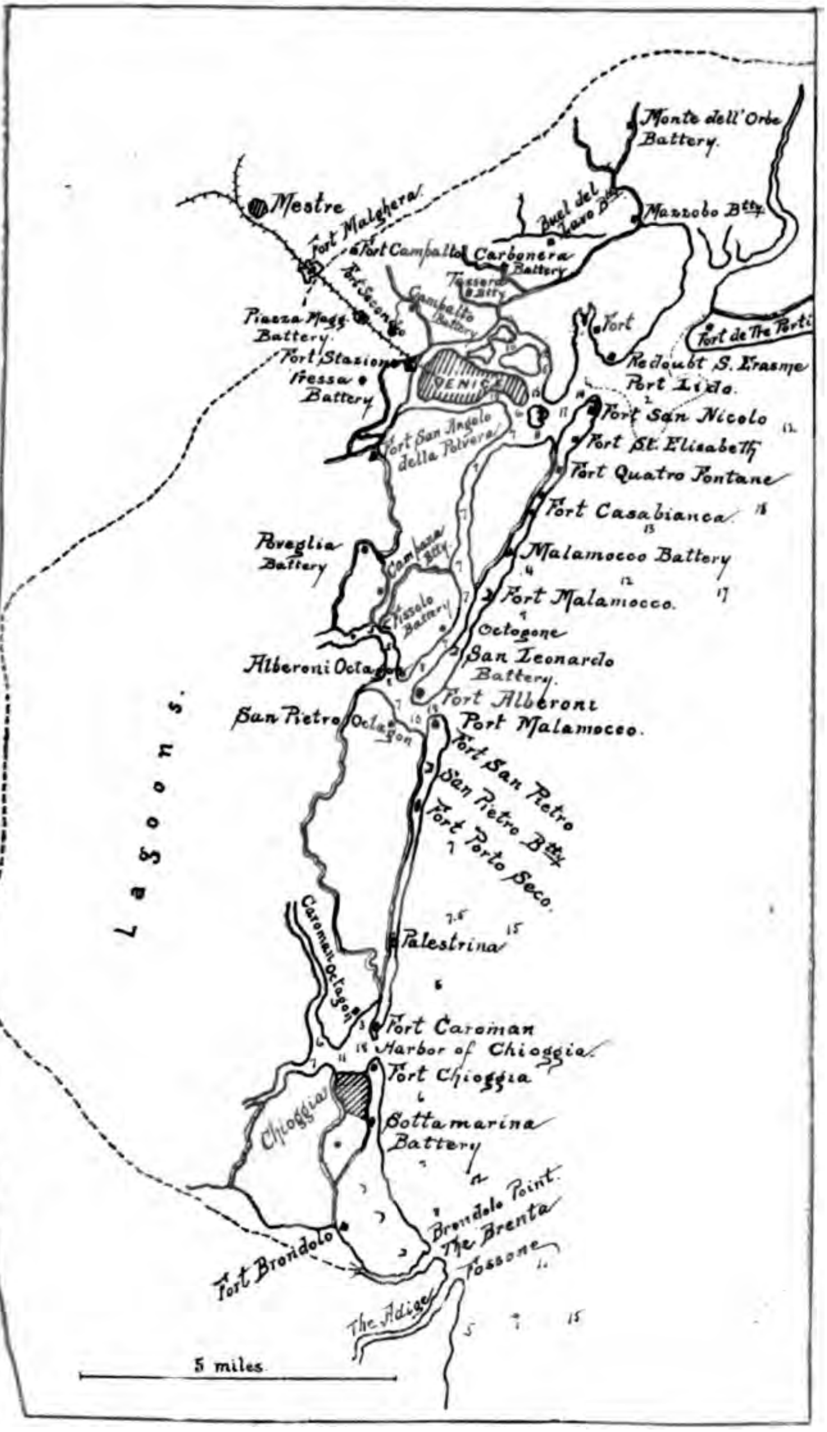
The coast defense commission, instituted in 1872, after nine years of study, resolved to do away with everything old in that line and to reject the erroneous system which lead only to a scattering of forces for the defense of the coasts. "Every port or harbor," it said in its report, "offering to the enemy a refuge from storms, etc., or facilities for disembarking, should be defended along the side towards the sea. Those maritime places only should be fortified on the land side that contain important works, arsenals, etc., or that co operate, by their position, in the scheme of the interior defense." Established on these principles, the plans of the commission leave not a single place on the whole coast of Italy where an enemy might disembark troops to make of it a base of operations for an expeditionary force. The greatest possible use has been made of what already existed; but, on the other hand, a great number of batteries scattered all along the coasts, according to old ideas, have been abandoned. The plan adopted at Spezia is entirely new and complete in every respect, as it was absolutely necessary to make certain the defense of this place both by land and sea; and this end has been completely attained.

"Spezia is to-day the great maritime arsenal of Italy and contains establishments all as complete as those of Toulon. But this port cannot alone suffice, as one is also essential for the coast of the Adriatic; and to connect the two and serve as a refitting port and place of rendezvous for the fleets—a base for any fleet guarding the coasts of Sicily and Calabria—a third port is necessary at the extremity of the peninsula."

Venice has been chosen as the military port on the Adriatic. Nearly twelve millions (francs) has been spent on important works at this place, for military and other purposes. Taranto fully satisfies the conditions imposed on the intermediate port between the other two: it is a magnificent position near the routes of commerce and of naval fleets.

The three great military ports of Italy are then: Spezia, the


N
La Magra Riv.
Battery St. Croce
Fort Monte Marcello
Fort Rochetta
Valestreri
Fort Branzi
Trebbia
Gaggiero
Lerici
Fort Canarbina
San Terenzo
Fort Maralunga
Fort Lerici
Canestrone
Fort San Terenzo
Fort Fresonara
Fort Capitole
Falconara Battery
Santa Theresa Batteries
Pianellone Battery
Fort Monte Bastia
San Bartolomeo Battery
Fort Val di Locchi
Fort Madona di Buon Viaggio
Fort Pozzino Bassa
Fort Santa Maria
Castagna Battery
Scuola Battery
Fort Palmaria
Porto Venere Bay
Grazie Bay
Fort Pozzino Alto
Porto Venere
Palmaria Passage
Palmaria Island
Tino Passage
Tino I.
Tinetto I.
Lem Battery
Capucins Batteries
Commercial Port
Cadinare Bay
Pyrotechnic
Chateau
Spezia
Arsenal
San Vito Works
Cadinare
Fort Mont Muzzerone
Fort Castellana
Fort Albano
Fort Cava Castellana
Fort Castellazzo
Fort St. Croce
Marinasco
Fort Parodi
Fort Biasso
Fort Samorigo
Vizzagi
Fort Verugali
Bramcapane Battery
1 mile.


Mestre
Fort Malghera
Fort Campalto
Carbonera Battery
Buel del Lovo Btty
Monte dell' Orbe Battery
Mazzobo Btty
Tessera Btty
Campalto Battery
Fort Secondo
Piazza Magg. Battery
Fort Stazione
Fressa Battery
Venice
Fort
Fort de Tre Porti
Redoubt S. Erasme
Port Lido
Fort San Nicolo
Fort St. Elisabeth
Fort Quatro Fontane
Fort San Angelo della Polvera
Fort Casabianca
Poveglia Battery
Campana Btty
Malamocco Battery
Fort Malamocco
Fisolo Battery
Octogone
San Leonardo Battery
Alberoni Octagon
Fort Alberoni
Port Malamocco
San Pietro
Octagon
Fort San Pietro
San Pietro Btty
Fort Porto Seco
Lagoons
Caroman Octagon
Palestrina
Fort Caroman
Harbor of Chioggia
Fort Chioggia
Chioggia
Sottamarina Battery
Brondolo Point
The Brenta
Fossone
Fort Brondolo
The Adige
5 miles

important construction arsenal; Taranto, refitting and repair arsenal, and place of rendezvous of the navy; and Venice, opposite Pola and Trieste, a point of support in the defense of the Adriatic coast.

(*a*) *Organization.*—The Italian coast (of a total length, peninsula and islands; of 4,240 miles[*]) is divided into three maritime *arrondissements* the headquarters of which are Spezia, Taranto and Venice respectively.

The maritime mobile defense is thoroughly and carefully organized. At Spezia, Venice, Naples and other cities, ships of the navy are stationed charged with the duties of coast defense. In addition, there are thirty-two stations for torpedo-boats,—divided into principal stations and secondary ones. The principal stations, fourteen in number, could offer a safe anchorage for about nine torpedo-boats. They have each a dry dock for repairs, a coal dépôt, storehouse for provisions (2,000 rations), a compressed-air pump, storehouse for two automobile torpedoes, and barracks for 50 or 60 men. The secondary stations, eighteen in number, possess the same accessories but reduced to the requirements of three torpedo-boats only. The crews of these small vessels are made up, preferably, from the sailors born or living in the district where they are stationed. Italy's naval force amounts to about 200,000 sailors.

The whole coast is connected by a system of semaphores[†], established at various points along it. This service was turned over to the navy in 1887, and from that time it has been thoroughly organized in anticipation of what should be expected of such service in time of war. There are now 63 stations and many new ones are in the course of construction.

(*b*) Artillery and coast defenses:

The artillery of the Italian coasts, of hooped cast-iron, is almost identical with that of the French of model 1864-66. It is composed of pieces of 16 cm. (6″.3), 24 cm. (9″.4) and 32 cm. (12″.5), and mortars of 24 cm. and 28 cm. (11″). The Italian 100-ton gun, 45 cm. (17″.5), of hooped cast-iron, mounted above Santa Maria at Spezia, is and will remain the sole example of a type the power of which has not fulfilled the expectations of the Italians and which does not satisfy the requirements of modern artillery.

The following table gives the principal pieces to be met with along the coast:

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[*] The length of coast line of the peninsula alone is 2,285 miles.

[†] Apparatus for signalling, furnishing means of communication from point to point. The semaphores are installed in small massive towers painted on the outside in checkered black and white.

Kind.	Caliber.	Weight.		I. V. f. s.	Maker.
		Gun in tons.	Projectile in pounds.		
Breech loading cannon.	45 cm. (17″.5)	101	2,200	1469	Rosset
"	40 cm. (16″.)	121	2,025	1790	Krupp
"	32 cm. (12″.5)	38.2	760	1540	Italian
"	24 cm. (9″.4)	17.7	330	1465	"
Breech loading mortars.	28 cm. (11″.)	—	—	—	Armstrong
"	28 cm. (11″.)	10.8	480	1020	Italian
"	24 cm.	4.5	262	750	"
Muzzle loading cannon.	16 cm. (6″.3)	4.5	66	1000	"

Italy, whose coasts, except those of Venetia, have a pronounced relief, does not seem to have considered introducing metallic shields and armored works in her system of defense. The batteries are mostly of earth. Of the numerous ones that rise above Spezia, for example, some are placed at such heights that all artificial protection is useless; others nearer the sea-level are provided with strong traverses, one for two pieces as a rule; finally others, and especially those which defend the channels, are low-lying casemated batteries of masonry, but without armored protection.

(*c*) Special considerations:

SPEZIA.—This is the greatest maritime arsenal of Italy. The place is most strongly fortified and armed, and the Italians place great confidence in the strength of it, their great military port. The new defenses of Spezia may be considered as practically finished. The whole of the defense amounts to about thirty works, mounting more than 300 guns, of which about 170 fire seawards, 100 landwards and 30 in both directions. The works firing towards the sea are armed for the most part with guns of 24 cm. and 32 cm. calibers.

The defenses consist of those of the west shore, those of the east shore and the land forts.

Of the first, there are ten forts and batteries at varying altitudes (627 to 310 m.). Fort Santa Maria is a huge work of masonry. Above the Santa Maria battery is mounted the 100-ton gun of General Rosset of hooped cast-iron. This rival of the huge Armstrong gun fires in barbette above an ordinary earth parapet; it has a field of fire of 70° and each shot requires six to seven minutes.

The *low* battery of Castagna, protecting the channels of the breakwater, is armed with three pieces of 40 cm. caliber.

On Palmaria Island are found: Fort Palmaria (alt. 187 m.) a bastioned work, recently renovated, and the armored battery of Scuola to the north-east. This work, and the one opposite on Maralunga Point, are the two most formidable defenses of the entrance of the gulf. They are similar. Each consists of an armored cupola-turret, 40 cm. in thickness, containing two Krupp guns of 40 cm. caliber. Armstrong has furnished the carriages, Krupp the guns, and Grüson the cupolas and turrets.*

The works on the eastern shore consist of 17 forts and batteries.

The Santa-Theresa *bassa* battery mounts three guns of 24 cm. caliber; the Santa-Theresa *alta*, situated immediately above the preceding, 8 guns of 32 cm. caliber.

Falconara battery has 12 guns, caliber 24 cm.

Pianellone battery is protected by cupolas; it also mounts 8 mortars, caliber 28 cm.

Fort Maralunga has been noted above.

Fort Rochetta is an important work armed with 26 guns and 4 mortars (alt. 415 m.).

There are about twelve forts and groups of works on the land side to the north of the gulf, forming the line of the land defense.

Fort Castellazo, among them, mounts 6 guns of 15 cm. and 3 of 9 cm. caliber.

Of the old fortifications, the Italians have preserved only Forts Santa-Maria and Palmaria, which they have completely renovated. The *low* sea-coast batteries are of masonry armed with guns of 32 cm. caliber.

Genoa is defended from an attack by sea by powerful batteries, about 11 in number, and is protected by three lines of forts on the land side. The new works are of earth. The most important of the sea-coast forts is the Lantern battery, a large work of two tiers of fire, mounting guns of 32 cm. caliber.

Naples is very much exposed to bombardment by sea. Its fortifications are of no great value to-day and altogether insufficient to protect it.

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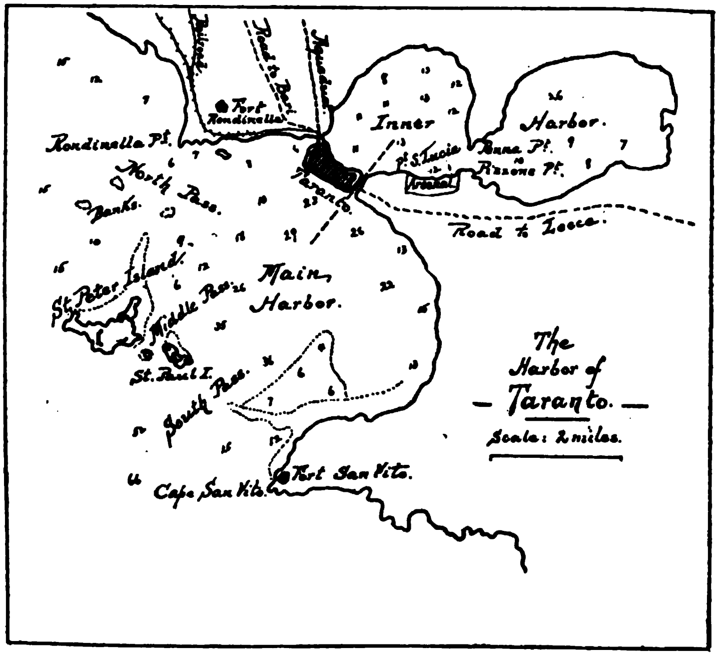
*The principal characteristics of these pieces are: cal. 40.2 cm.; weight 118 tons; length 14 m.; weight of projectile 1020 kg.; weight of charge (Fossano powder) 300 kg. (660 lbs.); range 8¼ miles. The projectile penetrates 91 cm. (35.5 in.) of steel at the muzzle, and 74 cm. (29 in.) at 2,000 meters.

TARANTO.—This is one of three important military ports of the peninsula. It was chosen as the place for a maritime arsenal by a decree of June, 1882, its position being preferred to that of Baia, Messina, Agosto and Syracuse, as fulfilling best the geographical requirements and possessing the requisite natural defenses.



The defenses of the place consist of Fort San Vito; the works on St. Paul Island; those on St. Peter Island; Fort Rondinella; and the *enceinte* of the city itself.

The natural advantages Taranto so fully possesses, render its defense most easy.

Ancona possesses little value from a maritime point of view. As a naval station, it has been abandoned. It is, nevertheless, a torpedo-boat station. About ten batteries protect the harbor and coast, while two lines of detached forts, together with the *enceinte* of the town, assure the land defense.

VENICE.—The maritime arsenal is in the eastern part of the city. The largest cruisers are built here. Its principal sea-coast defenses consist of:

1. Over seventeen forts and batteries along the coast to the south and east: Fort Alberoni is an important work, well armed. Lido Island is strongly fortified by many well armed works.

2. The interior defenses of the canals towards the south, and north of the city. The guns of about twelve batteries, built on the isles of the lagoons, cover the channels between the continent and the city. Most of these works are for the purpose of protecting Venice along the interior side; the batteries, open at the gorge, are exposed to fire from the offing, and would be of no value were the line of the sea-coast batteries reduced or silenced.

3. The continental defenses are intended to cover the railroad causeway, the only vulnerable point of Venice in this direction. Five forts and several batteries are placed along this causeway, Fort Malghera, the key of the position, commanding its commencement.

Maddalena Island, off the coast of Sardinia, has been strongly fortified as much on account of its exceptional natural advantages as the importance of its strategical situation. It is the site of a supply arsenal and a coaling station, and it is also one of the torpedo-boat stations. The Italian military engineers have constructed here some powerful works of recent date. They are built on the four islands Maddalena, San Stefano, Spargi and Caprera, and on the northern coast of Sardinia. Some of the works mount Krupp guns of 110 tons, besides several 100-ton and 68-ton guns.

GERMANY.

A vast and formidable system of fortifications is established along the whole of the German coast. The majority of the works are of recent construction and are armed with guns of new models.

A strategical railroad runs all along the coast from Emden to Memel, connecting all the ports directly to one another; branch lines connect the more distant ports with this main line which is put in communication with the interior of the country by about twenty railroads. Altona on the Elbe is the center of the defense, and is connected with Berlin and different points of the coast by underground cable.

(*a*) *Organization.*—The navy alone is charged with the defense of the coasts; it not only has to provide for that of the military ports, but it also has charge of the coast fortresses and all fortified maritime places. Thanks to this organization completed by a mobile defense by means of numerous and good torpedo-boats, Germany possesses to-day the most complete system of maritime defense of the countries of Europe.

The coasts of Germany are divided into two maritime districts: that of the Baltic Sea, and that of the North Sea. Each is commanded by a vice-admiral who has under his orders all the military and naval personnel of the district.

He is seconded by:

A rear-admiral, *inspecteur de la marine.*

An inspector of the marine cannoneers who have charge of the fixed defense of the coasts, batteries and torpedoes.

An inspector (Colonel) of the marine infantry (Kiel).

An inspector of torpedoes (Captain) who has charge of the automobile torpedoes and the mobile defenses. The garrisons of the "marine cannoneers" who serve the armament of the coast batteries (and also on board ship) are: Wilhelmshaven, Friedrichsort and Lehe in the estuary of the Elbe.

The submarine defenses are divided into the mobile defense and fixed defense (submarine mines). There are four principal stations (Wilhelmshaven, Kiel, Stralsund and Dantzig), and sixteen secondary stations.

(*b*) Artillery and coast defenses:

The artillery has four depots: Wilhelmshaven, Cuxhaven, Geestemünde and Friedrichsort. The principal pieces are given in the following table. Those most often met with are marked with an asterisk:

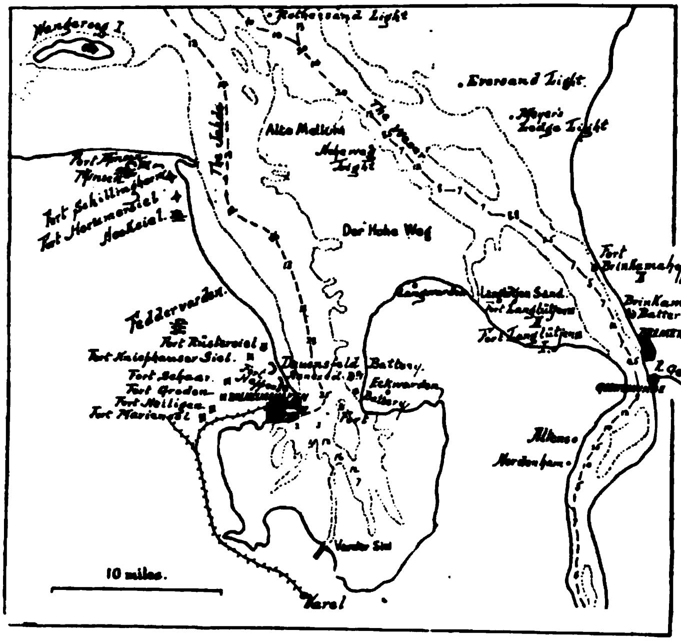
Caliber in Centimeters.	WEIGHT.		I. V. f. s.	Weight of charge. lbs.
	Gun in tons.	Projectile in lbs.		
45 (17.″5)	155	3146	1968	1118.
40 (16.″0)	72	1705	1646	451.
36.5 (14.″2)	75	1243	1646	590.
35.5 (13.″8)	52	1155	1640	253.
28* (11.″0)	27.5	515	1558	128.
26* (10.″1)	19 and 18	410	1584	105 and 125
24* (9.″4)	19	473	1656	50 and 66
21* (8.″2)	10	215	1463	41.8
15* (5.″85)	4.1	112	1624	15.4
12* (4.″68)	1.4	40	1545	8.8

The Germans make much use of the pieces of 21 and 28 cm. caliber; they have also rifled mortars of 21 cm. (8″.2) caliber. A series of much more powerful guns is being proved, 1894, consisting of cannon of 15, 24, 35.5, and 40 cm. caliber, and a rifled mortar of 28 cm.

The Germans, deprived on their low coasts of the advantages of command and obliged to place their batteries on the banks of sand that surround the water, have adopted a rational and well conceived system of armored batteries surmounted by turrets. The kind of armor and shields that has been chosen is that of Grüson make and the batteries and turrets are of his system. The batteries are casemated (of Grüson chilled iron), open to the rear usually, and when two tiers of fire are thought necessary, the battery is surmounted by one or more revolving cupola-turrets of the same Grüson make.

(*c*) Special considerations.

THE JAHDE, WILHELMSHAVEN.—The entrance of the Jahde, protected on the east by shoals, is defended on the west by the work on Wangeroog island, Fort Minsen and its detached batteries, and the batteries of Schillinghorn and Horumersiel. These works are armed with pieces of 30.5 cm. caliber, firing under armored cupolas, guns of 28 cm. caliber, rapid-fire guns, caliber 56 mil., and mortars of 24 and 28 cm. caliber.



Wilhelmshaven is a great military port possessing all the most modern improvements. Its defenses have been added to and strengthened continually since 1870. Along the sea front are found (among the works at the entrance of the bay):

Fort Heppens, 19 guns; a battery in front, 7 guns; Dauensfeld battery, 15 guns of large caliber; Eckwarden battery that has been rebuilt and improved. A new work on the bank between Wilhelmshaven and Eckwarden enfilades the channel.

Six forts defend the land front.

THE WESER.—The mouth of the Weser is most strongly fortified. Here we find four important forts heavily armed, two on each bank. On the right bank (or eastern):

Fort Imsum or Brinkamhoff, provided with four armored cupolas; three of these cupolas carry each two guns 28 cm. in caliber; the fourth, turned towards the land, contains 2 pieces of 15 cm. caliber.

The Brinkamhoff armored battery armed with ten 21 cm. guns, south of the preceding. These works are provided with hydraulic apparatus for maneuvering the turrets and the guns. The plant is near the river bank between the two; it permits, simultaneously, the turning of the three turrets and the pointing and aiming of six large pieces.

On the left bank (or western) on the large Langlütjen shoal stands:

Fort Langlütjen Sand, No. 1.—An armored battery mounting nine 21 cm. guns.

Fort Langlütjen Sand, No. 2, with 6 armored cupolas, five of which are each armed with a single gun, caliber 28 cm., and the sixth with two 15 cm. guns turned towards the land. In these two works, the maneuvering of the turrets and the service of the pieces are done by hand, the total weight not exceeding 500 tons. A complete rotation can be made in six minutes, and two men suffice for the operation. The guns fire nearly 30 shots an hour, whatever the rotation of the turret.

The Elbe is the most important river of Germany from a commercial point of view. The mouth of the Elbe, which in 1870 was defended by some hastily built batteries, has since then been fortified by numerous and powerful works.

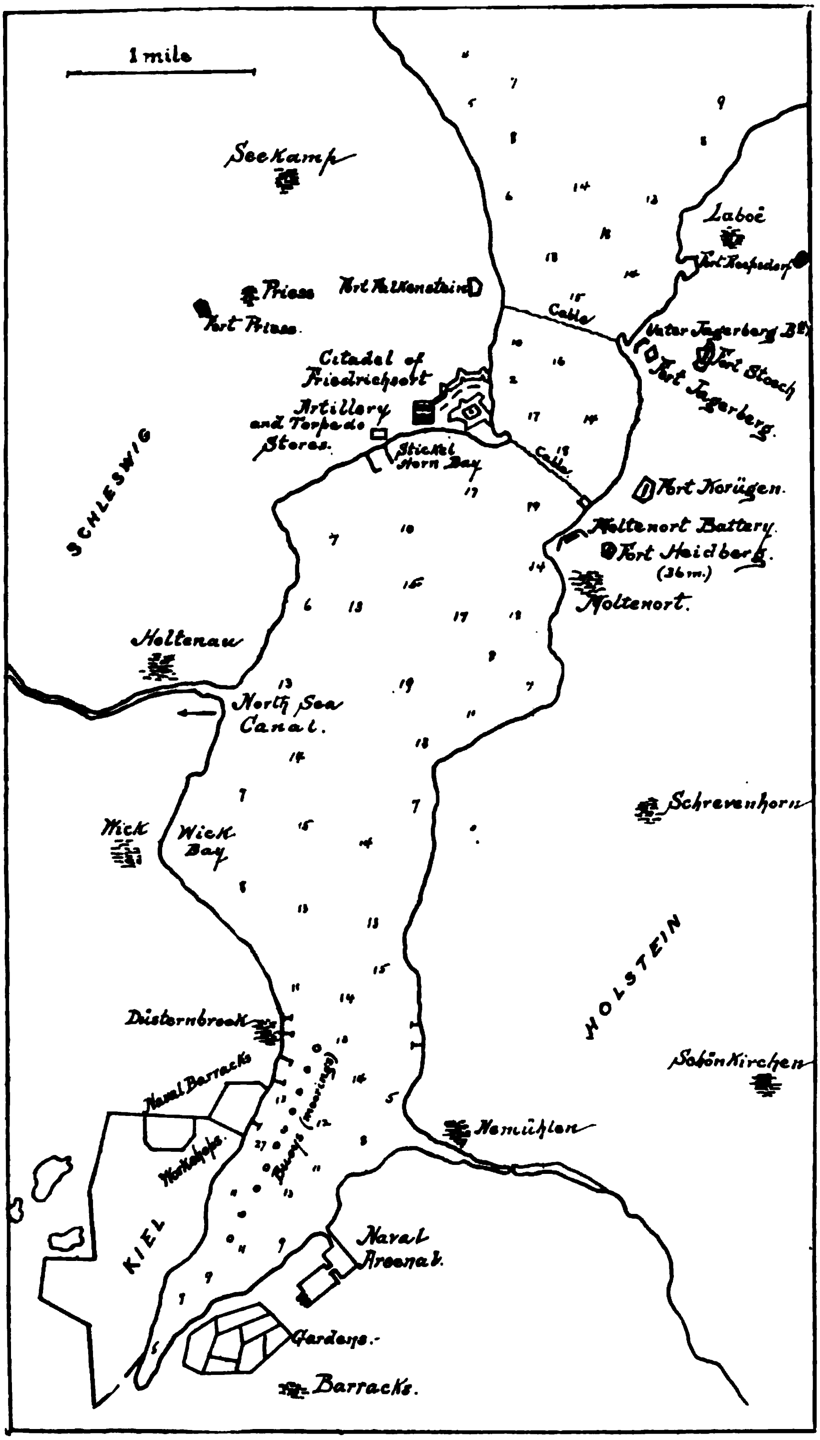
On the left bank may be mentioned:

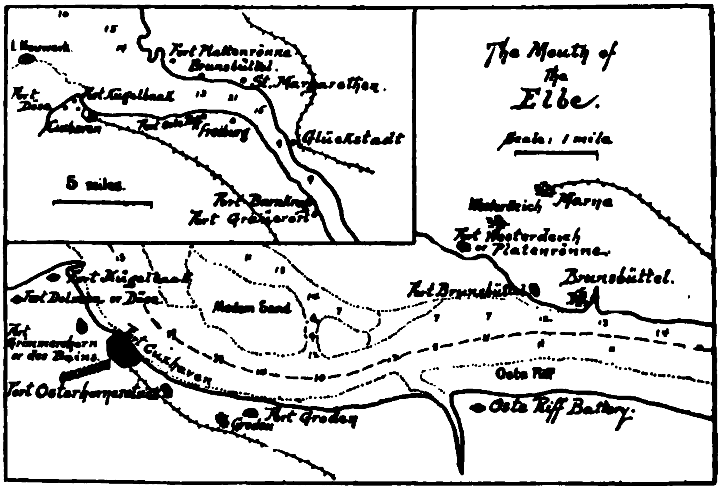
The fort on Neuwerk island, a recent work armed with Krupp 45 cm. guns.

Forts Kugelbaak and Grimmershörn, earthen works that have been recently enlarged and improved. They each mount 8 guns, 24 cm. caliber, of the latest model.

Fort Döse or Dülmen, with 3 armored cupolas, containing 35 cm. guns.

Forts Osterhornerstack (6 pieces), Groden (8 pieces), Barnkrüg


1 mile
Seekamp
Priess
Fort Falkenstein
Fort Priess.
Laboë
Fort Reepsdorf
Cable
Vater Jagerberg Bty
Fort Stosch
Fort Jagerberg.
Citadel of Friedrichsort
Artillery and Torpedo Stores.
Stickel Horn Bay
Cable
Fort Korügen.
Moltenort Battery.
Fort Heidberg. (36 m.)
Moltenort.
SCHLESWIG
Holtenau
North Sea Canal.
Schrevenhorn
Wick
Wick Bay
HOLSTEIN
Düsternbrook
Naval Barracks
Workshops.
Buoys (moorings)
Schönkirchen
Neumühlen
KIEL
Naval Arsenal.
Gardens.
Barracks.



(5 pieces), Grauerot (10 pieces) of earth and heavily armed; the armored battery of Oste-Riff, and the new Fort of Cuxhaven. These forts are armed with 24 cm. guns, latest model, mounted on sea-coast center-pintle carriages which allow 44° elevation and 4° depression.

An armored battery and Fort Brunsbüttel are in course of construction on the right bank.

The island of Helgoland has been fortified, the Germans having continued the work commenced by the English. There is a battery of 100-ton guns on the southern point about 55 m. above sea-level, and a battery of four 32-ton guns on the west side.

It is at Kiel, however, that the most superb works have been built.

KIEL.—The fortifications may be considered under two heads:

a. Those intended for the defense of the entrance of the harbor. These works arranged in two lines on each side of the channel, are about 9000 m. (9750 yds.) from the arsenal. On the west side they consist of:

Fort Priess (alt. 39 m.), a semi-maritime work of the very first order. This fort consists of two covered batteries, armored, mounting 24 cm. and 15 cm. guns (roof covering of plates 250 mm. thick); two chilled-iron turrets (Grüson), each containing two 20 cm. guns, covered by cupolas (49.5 cm. in thickness); two open batteries of concrete and granite for 28 cm. mortars; three turrets, each containing two 10.5 cm. guns; and finally three caponnières, each armed with 4 revolving-cannon, caliber 52 mil.

Fort Falkenstein (alt. 35 m.), affording plunging fire on Brauneberg.

The citadel of Friedrichsort, direct fire on the channel.

On the east side:

Fort Roepsdorf, a semi-maritime work similar to Fort Priess. It contains two covered batteries, armored, (roof plates 20.6 cm. thick), mounting 28 cm. and 21 cm. guns; three Grüson turrets, each containing two 30. cm. guns, covered by cupolas (49.5 cm. in thickness); two open mortar batteries for mortars of 21 cm. caliber; two turrets, each containing two 10.5 cm. guns; and 4 caponnières each armed with 4 revolving-cannon, caliber 52 mil.

There are also: Forts Stosch, Jagerberg, Korügen and Heidberg (plunging fire permissible), and the batteries of Unterjagerberg and Möltenort, direct fire across the channel.

b. The fortifications intended to prevent a direct attack on the arsenal and city.

These works are as yet only planned or in course of construction, but the completion of the North Sea Canal renders their execution imminent. Altogether they will consist of about 14 works at a distance of 6 km. from the city.

The harbor of Kiel is defended also by 79 Herz electro-automatic torpedoes divided in three lines. One line lies between Friedrichsort and Möltenort.

Stralsund is fortified and defended by about six batteries mounting heavy guns. For a long time this was one of the strongest places in Europe.

Swinemünde is a port of great importance strategically. Its defenses, a recently restored fort and two large batteries of earth, are not armored, however, nor have they any cupola-turrets; but the Germans are considering placing armor on these defenses.

The defenses of Dantzig are also receiving much attention of recent years. At least a part of them will be armored. At present they consist of about 17 forts and batteries and the works on Holm Island, all of which have been renovated and improved. It is proposed to make Dantzig a military port of the first order, a maritime arsenal near the Russian boundary to offset the Russian military port at Libau.

Pillau-Königsberg is the key of eastern Prussia. The approaches to Königsberg are ably defended and protected by the defenses erected at Pillau. These consist of: the citadel, a pentagonal bastioned work that has been considerably improved and strengthened of late, armed with heavy guns and provided also with Grüson armored cupolas; two advanced lunettes of the citadel; the fortified enceinte of the new city, of earth; the West Fort, a closed work built of earth mounting three heavy guns; the East Fort, an hexagonal redoubt strongly armed. These two forts have also some Grüson armored cupolas.

The system of fortifications of Königsberg consists of an enceinte and a line of thirteen detached works.

General conclusions:—England, France and Russia have had to improve, strengthen, and modify what already existed in the line of their sea-coast fortifications, hence any well defined system is not apparent. Their guns, too, of old models are being replaced by those of new design. It is among such powerful maritime nations that improvements of this class absorb most of the appropriations for the defense of their coasts, because they already have these batteries and forts that they hardly dare at once abandon or dismantle. This is true, to a certain extent, of Italy also. On the contrary, the new maritime power, Germany, free from all such burdensome inheritance, has been able to throw herself boldly into the very first line of progress. In these really modern systems no expense seems to be spared in making the defense as strong and as impregnable as possible, aided by the fire of guns of the heaviest calibers.

Much discussion is had as regards making guns of smaller calibers, but with the exception of the 6″ guns of the English, the facts seem to offer no justification therefor; 9″, 10″, 12″.5 and in Germany even 15″ and 16″ guns are now being manufactured.

Due to improvements in carriages and mountings, the weights have become more manageable, and steam and hydraulic power have been brought into requisition.

And finally it may be interesting to know that no fortification, built previous to 1885, is in a condition to resist torpedo-shells or shells with the new explosives for bursting charges. At present, a very limited number of places have been remodeled and put in condition to fulfil modern requirements.

If Antwerp, for example, a place considered most strong, were attacked to-morrow, how long would it offer resistance? Some engineers go so far as to say it could be taken by assault in 48 hours. It is well to bear in mind this state of affairs, when reading about the formidable defenses of a great part of the European coast. However powerful they may be, the armored warships, carrying heavy artillery and furnished with modern projectiles is well able to cope with them.

Lieutenant ANDREW HERO, JR.,
Fourth Artillery.

REPORT ON DEVELOPMENT OF A PHOTO-RETARDOGRAPH AND ITS APPLICATION TO THE DYNAMIC MEASUREMENT OF RESISTANCE TO COMPRESSION OFFERED BY THE COPPER CYLINDERS USED IN CRUSHER GAUGES.

By First Lieutenant B. W. DUNN, Ordnance Department, U. S. Army.

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INTRODUCTION.

The tarage tables for crusher gauges are prepared from static testing machine data. In this machine each successive load is allowed to act for a uniform time—about 15 seconds—before measurement to obtain corresponding shortening of copper cylinder. In practice, where an initially compressed cylinder is used, the only time available for producing further shortening is that during which powder pressure exceeds the initial load on copper. The ratio of this time to the 15 seconds interval can not be far short of the ratio 1 : 1,000,000. The copper cylinder is an exceedingly delicate balance and yet it is necessary for its registration that a quantity of matter in cylinder itself even be put in motion. When two equal loads, capable of producing such motion, are sustained during times that are in the ratio of 1 : 1,000,000, it would seem that a difference between effects produced must follow.

We have some data relating to effect of varying time of action of static loads. The first two of the following tables are taken from "Tests of metals, 1888," and the third comes from records of the same machine, the experiment having been made at the request of the writer in 1891.

A copper was loaded with 28,000 pounds per square inch [actual load 1,381 pounds] compression with the following results:

Total compression.	Time load was sustained.
inch.	
.0365	1 second.
.0370	1 minute.
.0372	4 minutes.
.0373	9 minutes.
.0374	49 minutes.

Another copper was loaded with 60,000 pounds per square inch compression [actual load 2,958 pounds] with the following result.

Total compression.	Time load was sustained.
inch.	
.1149	2 seconds.
.1163	1 minute.
.1173	4 minutes.
.1182	9 minutes.

Another copper was subjected to successive loads of 20,000, 25,000, 30,000, 35,000, and 40,000 pounds per square inch (crusher gauge), or actual loads of 2,000, 2,500, 3,000, 3,500, and 4,000 pounds, each load being sustained as long as the copper continued to decrease appreciably in length. The first measurement for shortening was taken as soon as possible after application of load and the others at the end of times specified in second column. The successive differences of these measurements appear in third column. The errors in indicated powder pressures that would correspond to these increased shortenings appear in fourth column.

Load.	Total time sustained.		Increased shortenings.	Errors in pounds per square inch, crusher gauge.
Pounds.	*Minutes.*	*Seconds.*	*inch.*	
2,000	1	5	.0009	156
2,500	1	30	.0033	600
3,000	2	45	.0033	628
3.500	4	30	.0052	904
4,000	4	20	.0062	1.303

Nobel, Sarrau, and Vieille have reached the conclusion that the effect of variations in time is inappreciable. Sebert and Hugoniot find that crusher-gauge records are between 300 and 400 kilograms per square centimeter (4,267 and 5,689 pounds per square inch) lower than the maximum pressures obtained by use of free recoil carriage. The hope that he might, to some extent, throw additional light on the subject induced the writer to undertake the investigation described in the following pages. The investigation was begun, by authority of the Chief of Ordnance, during the summer of 1891, and the conclusions, hereinafter stated, were formed before the writer learned of the work of Sebert and Hugoniot. These gentlemen obtained a dynamic measure of powder pressure and the writer has attempted to obtain a limited dynamic tarage of crusher gauge. This paper is submitted as a contribution to the crusher-gauge discussion.

GENERAL PRINCIPLES.

When a piece of metal (such as a cylinder of pure copper, annealed, 0.5 inch long and 0.25 inch in diameter) is compressed by a falling weight of known mass and known energy at impact, the relation between the successive compressions of specimen and the times occupied in producing them is expressed by the equation

$$t = f(c) \quad \ldots\ldots \quad [1]$$

in which t represents time and c compression. If the form of this function were known we could ascertain the resistance R, of the specimen, for any value of c, by substituting in the expression $R = \left(M\frac{d^2c}{dt^2} + W\right)$ the value of $\frac{d^2c}{dt^2}$ obtained from [1] by differentiation, M and W, the mass and weight of falling weight being known. In the absence of knowledge as to the form of the function $t = f(c)$, we may still obtain approximate results by graphical differentiation of an experimental curve, the ordinates of which are represented by c and the abscissas by t in equation [1].

The degree of approximation to the true values of R will depend upon: (1) The accuracy with which the ordinates and abscissas of the experimental curve represent the true values of c and t; (2) the accuracy with which we can measure these ordinates and abscissas, and (3) the rate of change in the true values of R. In graphical differentiation we are compelled to use a comparatively large value for dt and to assume a uniform change both in c and in $\frac{dc}{dt}$ for this interval. This involves no great error provided the true values of R at the point in question do, without sensible error, vary directly with either c or t. All of our static data indicate that after the initial stages of compression are passed, R may be assumed for long intervals as increasing directly with c. We can so regulate the mass and height of fall of our compressing weight as to produce a given compression of copper cylinder in a time* approximately equal to continuance of powder pressures in gun. To do this and furnish data for constructing resistance curve of specimen, as a function of c, are the conditions imposed upon the apparatus hereinafter described.

DESCRIPTION OF APPARATUS.

Plate I shows the apparatus as first constructed and illustrates all principles involved. Improvements in details that were introduced will be described later. The central idea is to produce by the aid of photography the curve whose equation is represented by the unknown function, $t = f(c)$.

The essential parts of the apparatus are—

First.—A solid foundation, as unyielding as possible, upon which specimen rests when it receives, through steel piston, the blow of falling weight. In preliminary experiments this was obtained by utilizing an old hydraulic press at Watertown Arsenal.

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* In obtaining and differentiating experimental curves the mechanical difficulties increase rapidly as the total time of compression decreases. The time required by powder pressure to rise to a maximum is about 0.001 and the shortest time consumed in producing a total compression in this investigation was about 0.003 second This matter will be discussed later in this report.

Later, when it became necessary to transfer this work to San Antonio Arsenal, a steel anvil, 10 inches in diameter and 12 inches long, was embedded in a mass of concrete 4 by 2 feet by 6 feet in depth, filling a hole of corresponding dimensions in dry earth. The upper face of this anvil was accurately adjusted to a horizontal position.

Second.—A housing to receive and center the specimen and to act as a guide for the hard-steel piston which receives blow and transfers pressure to specimen.

Third.—A rigid guide pipe, accurately bored, to keep axis of falling weight vertical and to regulate height of fall.

Fourth.—A series of weights, one shown at W, provided with hard-steel impact plugs and having cross section as shown in Fig. 2.

Fifth.—A cylinder (C) arranged to revolve rapidly about a vertical axis on adjustable hard-steel centers. Around this cylinder a sensitive celluloid film is wrapped, a perfect glove fit being secured. To prevent vibrations, due to rapid revolution, and to prevent film being accidently "light-struck," a heavy cast-iron box with a vertical slit to admit pencils of light was introduced to support and inclose this cylinder. The drum and gearing used to produce rotation was attached to this box.

Sixth.—A small mirror (Figs. 6 and 7) arranged to revolve about a fixed horizontal axis and connected with piston so that the extent of revolution depends directly upon upward or downward movement of piston. For the slotted arm shown in drawing, two hard-steel links, each 1 inch long, revolving about hard-steel pins were substituted (Fig. 5). The pins and their bearings, as well as adjustable conical bearings for fixed mirror axis were ground to as accurate a fit as mechanical skill could produce.

Seventh.—A rapid tuning fork (F), of known rate, mounted horizontally (Fig. 1), with means provided for setting up vibration just before impact. The photographic record of fork is obtained by directing a horizontal beam of light of diameter less than width of prong on one of the small holes shown in Fig. 1. During vibration the hole is always wtthin the beam and no light gets to lens L‴ other than that passing through hole.

Eighth.—The mirrors, pipes, etc., necessary for furnishing two beams of light, one directed through a combination of lenses (L′ and L″) to center of revolving mirror and reflected thence to surface of cylinder C; the other directed through hole in fork and the lens L‴ to same surface. The first beam furnishes a reduced, intensely bright, and well defined image of the sun;

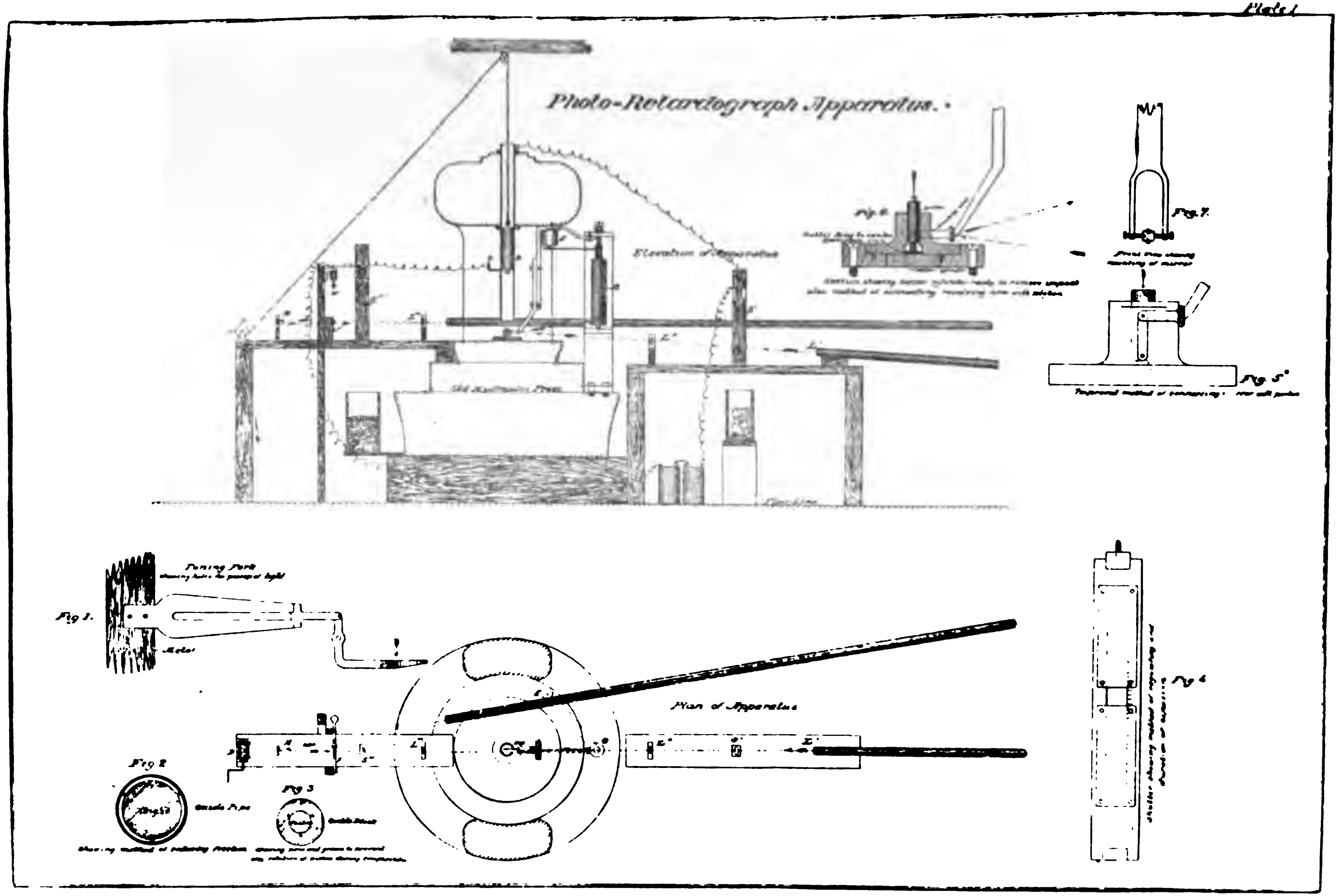


Photo-Retardograph Apparatus.

Plate II

PHOTO-RETARDOGRAPH

COMPRESSION OF COPPER CYLINDERS

GRAPHICAL ENLARGEMENT OF NEGATIVE No. 7

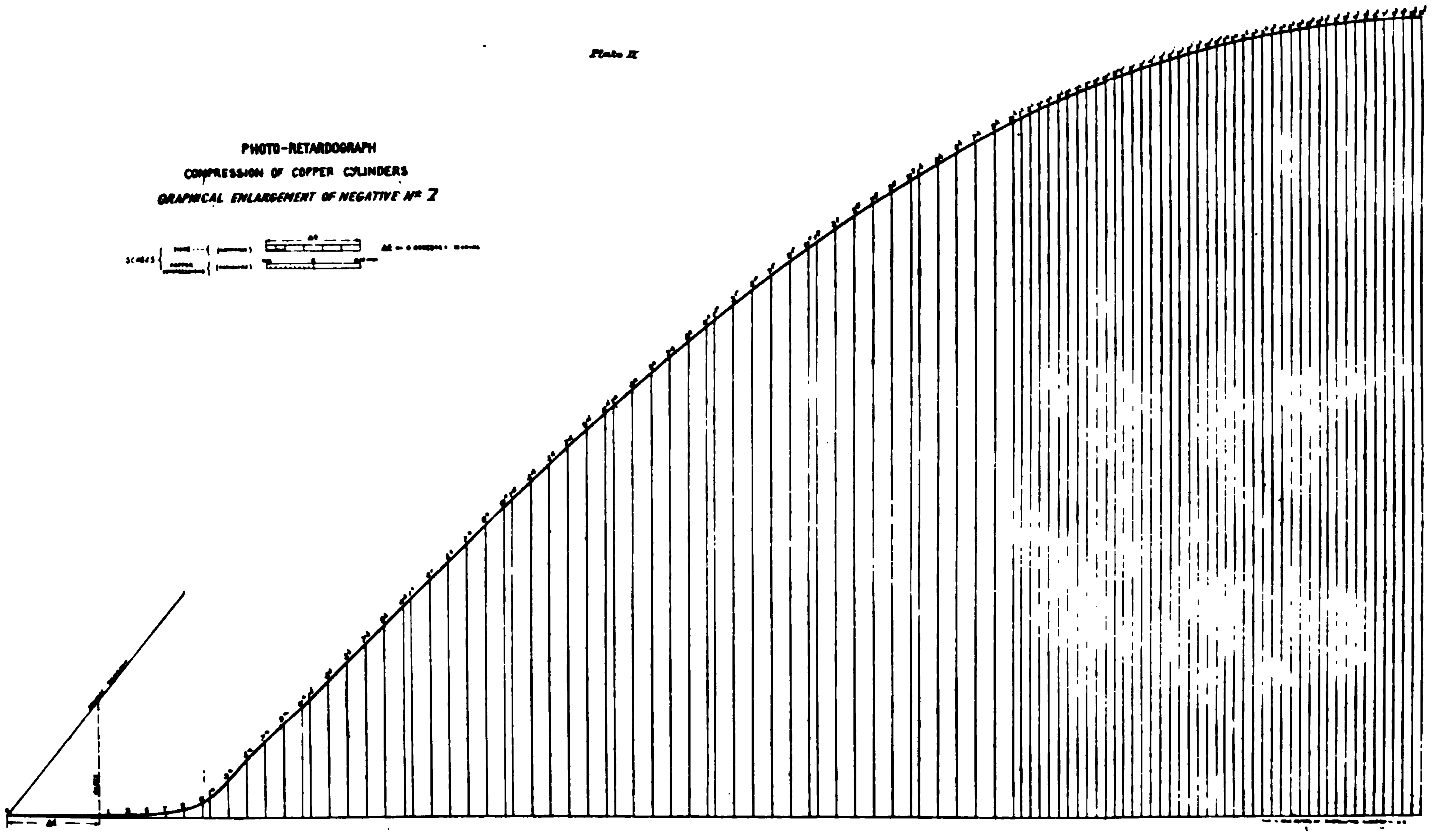
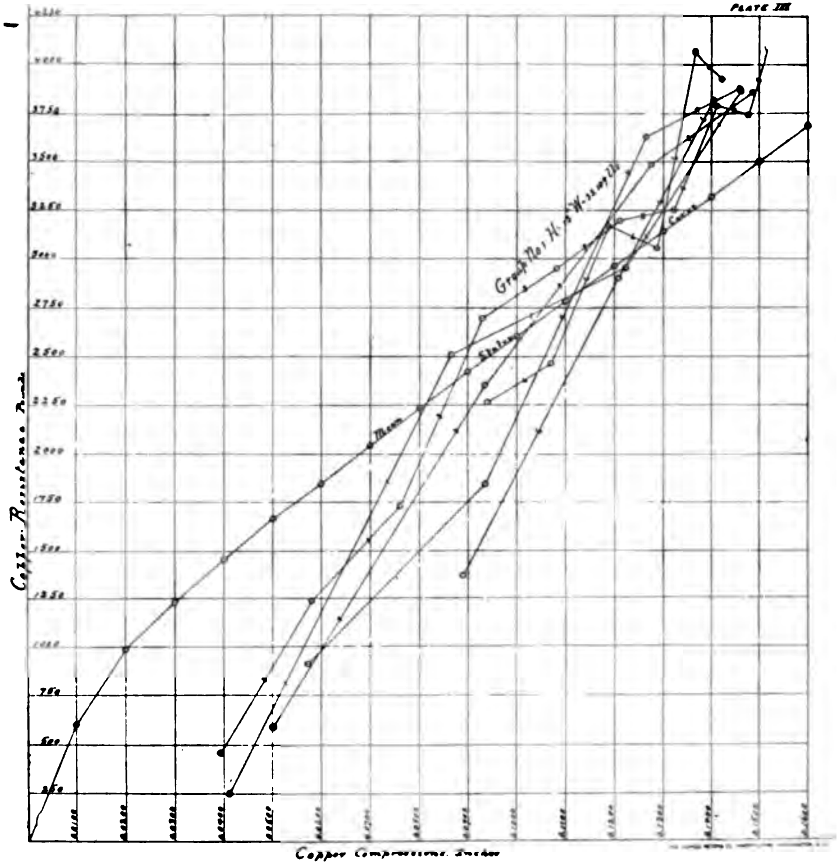
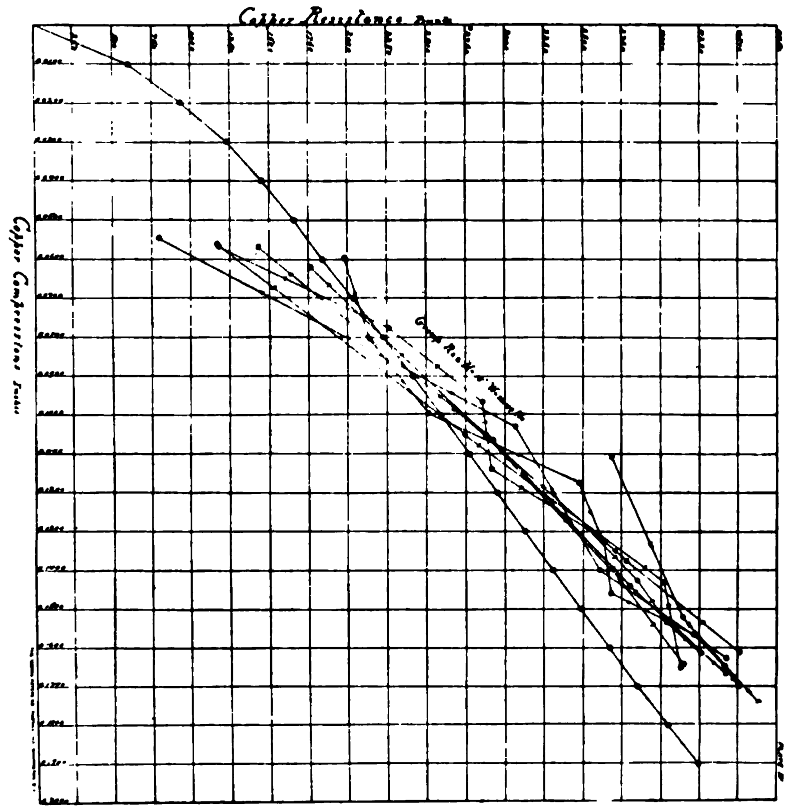


PLATE III


Copper Resistance Pounds
4000
3750
3500
3250
3000
2750
2500
2250
2000
1750
1500
1250
1000
750
500
250
Copper Compressions, Inches
Group No. 1 H. & W.
Mean
Curve


Copper Resistance Pounds
Copper Compressions Inches

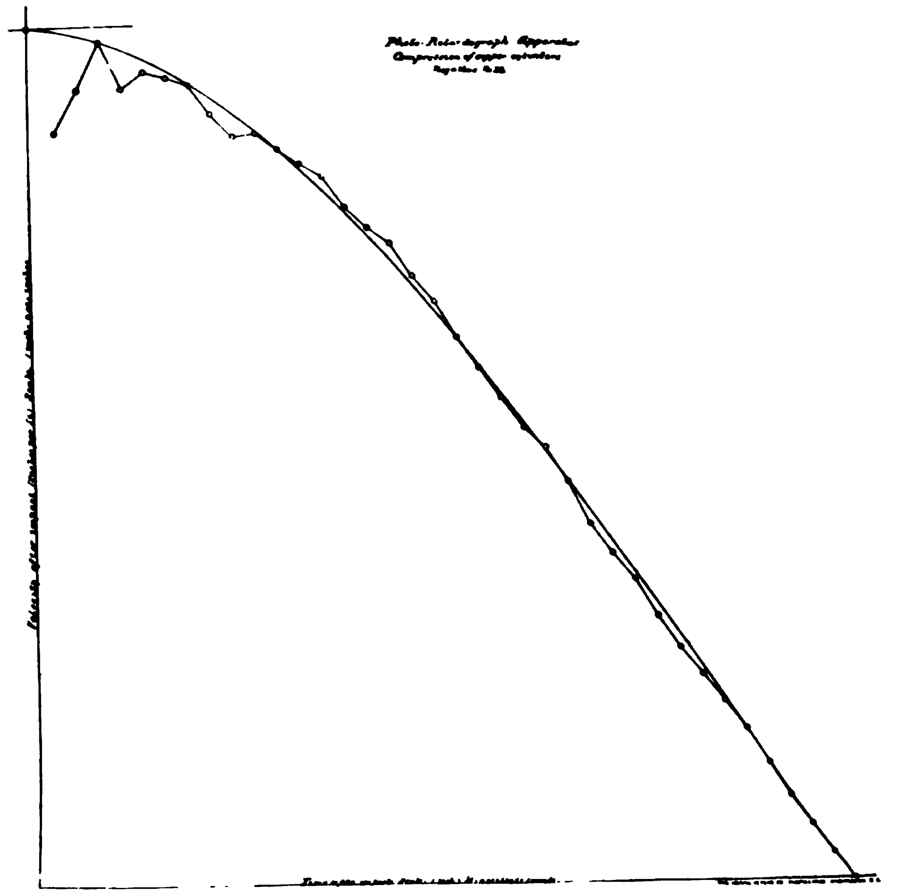
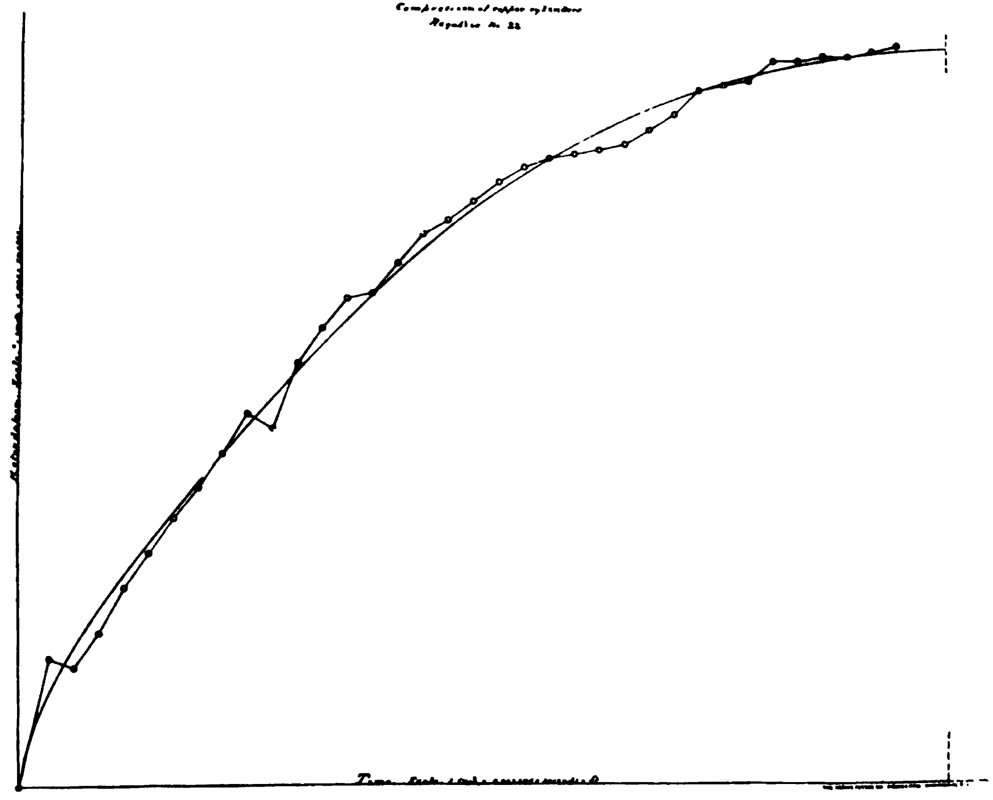
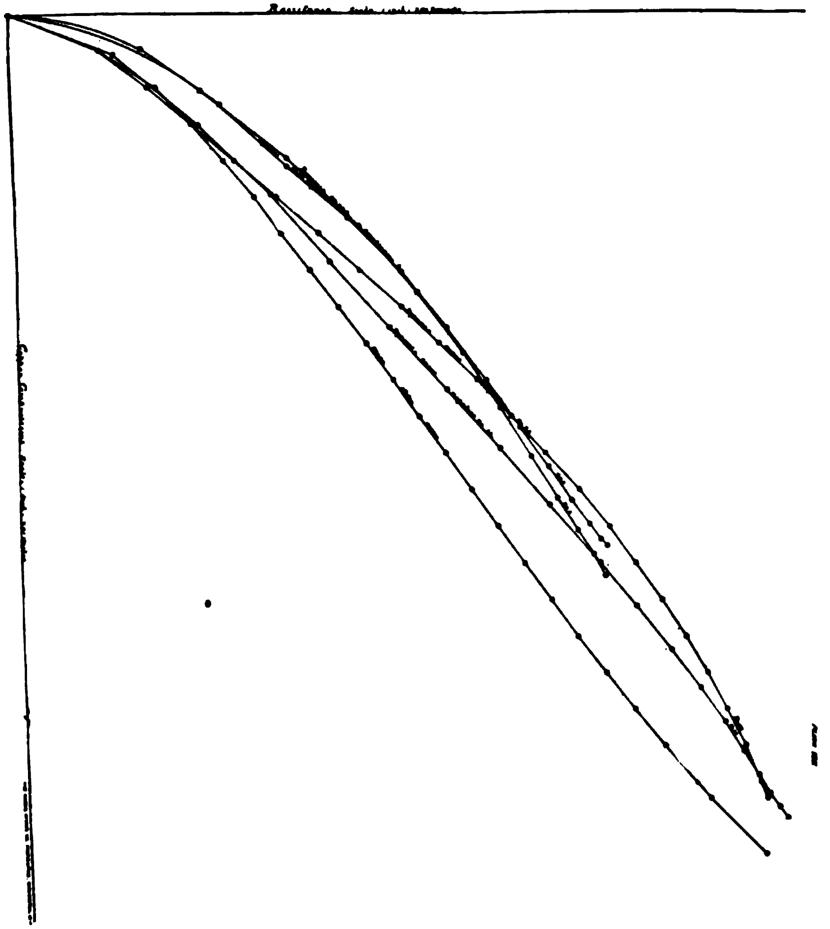


Photo-Retardograph Apparatus
Compression of copper cylinders
[illegible]
Velocity after impact [illegible] Scale 1 inch [illegible]
Time after impact Scale 1 inch [illegible]
[illegible]

Photo Retardograph Apparatus
Compression of copper cylinders
Negative No. 23

Plate VII





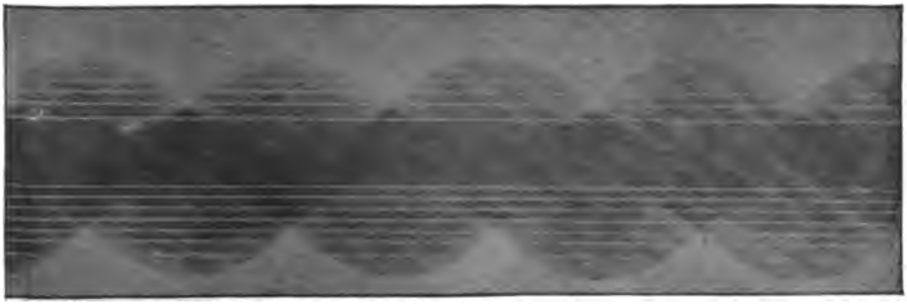


FIGURE 1.

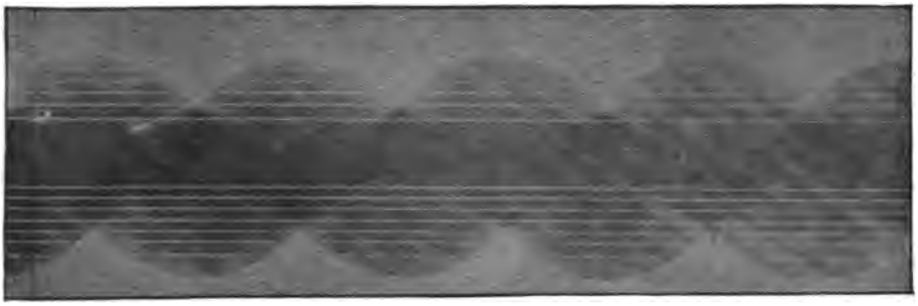


Figure 1.

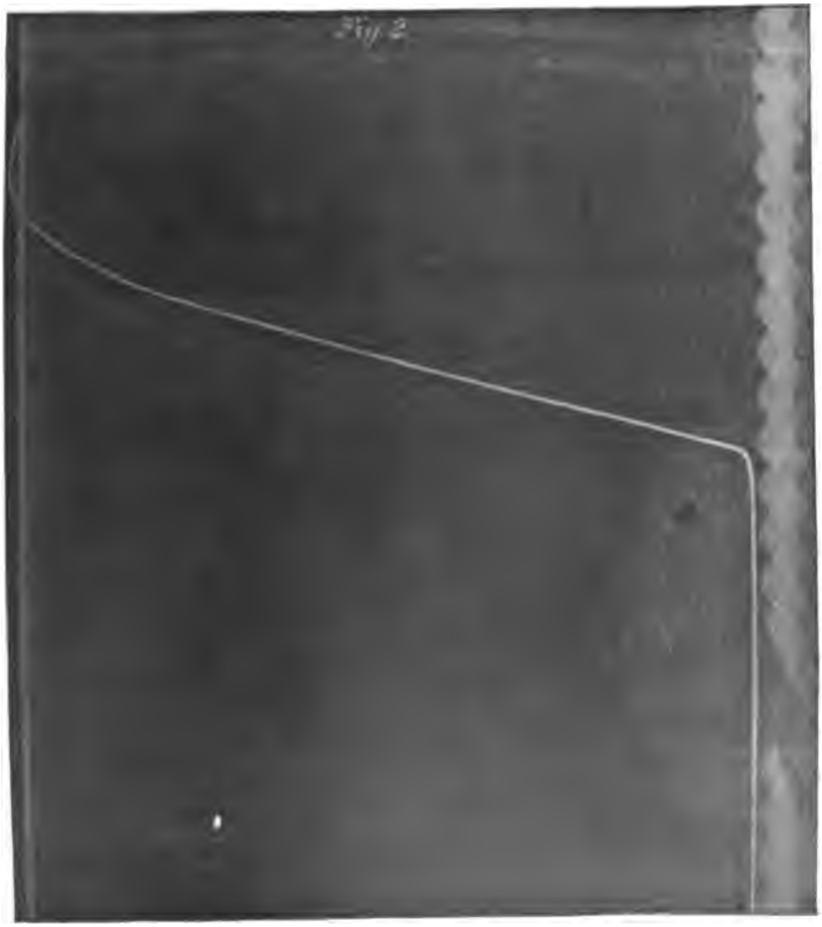
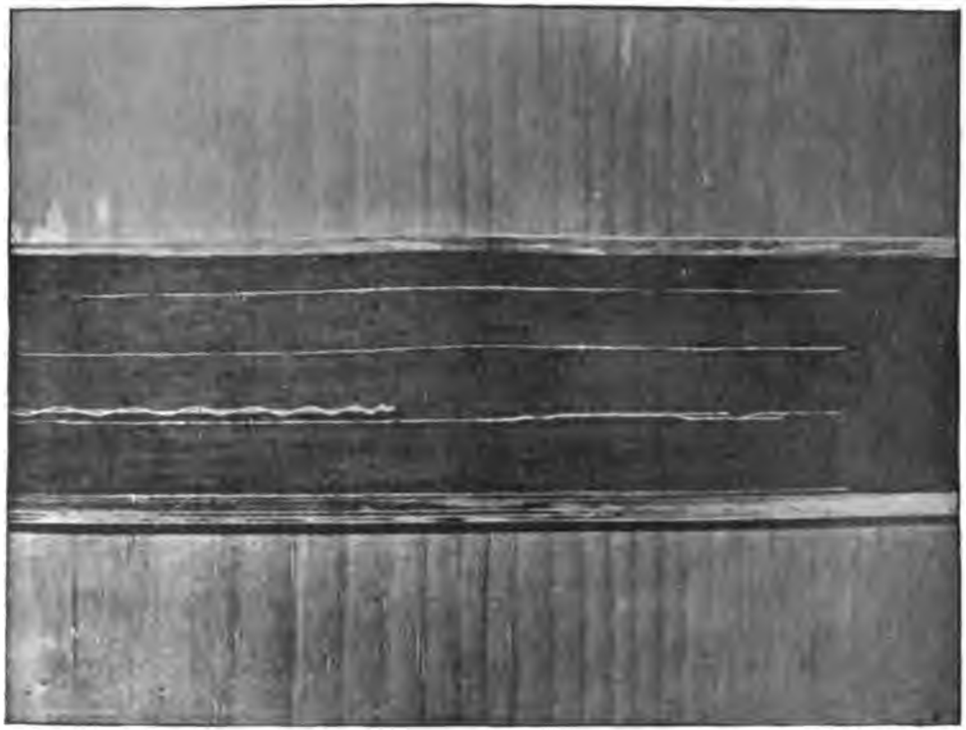


Fig. 2



VIEW SHOWING RIBBON WITH ITS RECORD.
Report, Lt. Wheeler.

the other a corresponding but enlarged image of circular hole in fork. The centers of these two images are adjusted to same element of cylinder C. The first traces the experimental curve and the second traces simultaneously a time scale for the horizontal distance passed over by film during compression of specimen.

Ninth.—Very accurate means for turning on and off these two beams of light. With the speed used, the cylinder C completed very nearly one hundred revolutions per second and to make the average curve required only about one-third of one revolution. It was necessary to turn on the lights just before impact and to turn them off again (especially the tuning fork image) before completion of revolution of cylinder. A failure to do this in the case of the tuning fork light would result in overlapping of time scale. The tuning fork must also be set vibrating just before light is turned on in order to secure its record with maximum amplitude. The high fork used (over 4,200 simple vibrations per second) does not maintain a satisfactory amplitude for more than a few hundredths of a second. All of these conditions were met very satisfactorily by the gravity shutters shown at *s'* and *s''* and in detail in Fig. 4. While shutters are suspended, lights are off, and during their fall, the beams affected are turned on while slides are passing over distances corresponding to adjusted openings. The known height of fall H, of weight W, permits adjustment of shutters so as to turn on lights just before impact, and a similar adjustment for the small weight used to release fork enables us to set it vibrating at any desired instant. The speed of cylinder being approximately known, the proper widths of openings in shutters follow. As will be seen, the simple act of knocking out metal pin which sustains weight W, releases this weight and by breaking the electrical contact it releases the shutters and tuning fork weight as well.

Tenth.—Power to give rapid rotation to cylinder C. The drawing shows an electric motor for this purpose. This was replaced later by a system of multiplying cogwheels and a drum, the cord from drum passing to an auxiliary falling weight weighing about 100 pounds. The end of the cord was not fastened to drum, with the result that, when this cord was unwound, it was disconnected entirely from drum and the cylinder was left with its maximum speed to be gradually reduced by friction. This auxiliary weight was used to operate an adjustable trigger, which, by pulling out the pin P, released the weight W, and at a time such that impact of W on the steel piston occured just as the cord became disconnected from drum. By this means the photograph was secured just as acceleration of cylinder was passing through zero, and at this stage it was beyond the power of measuring instruments to detect, from the negative, and for the interval of time used to obtain record—about 0.004 second—any variation in plate velocity. These favorable conditions were not secured by use of the motor.

It is thus seen that after the different parts are "set ' the entire apparatus is automatic. Before making an experiment the room is, of course, darkened. The operator, when everything is "set," releases the auxiliary weight. It rapidly speeds up the cylinder C, and after falling a determined distance, releases the weight W by pulling out pin P. At almost the instant that W is released (magnetic lag causing the only difference in time) the shutters s' and s'' and the small weight w' begin to fall as a result of stoppage of electric current through magnets which had sustained them. A few thousandths of a second before W reaches the piston, acceleration of cylinder speed is stopped by disconnection of cord from drum; the weight w', by its action on lever shown in Fig. 1, pulls out wedge and sets the fork vibrating; the opening in shutter s' is opposite its pencil of light and the image of sun appearing at bottom of revolving cylinder begins to trace axis of abscissas of experimental curve; the shutter s'' in like manner permits moving image of hole in fork to appear just under the sun image, on same vertical element, where it begins the tracing of sinusoid or time scale. After impact, as the steel piston moves downward, following up the yielding of copper specimen, a corresponding rotation of mirror follows and the sun image moves up the element of revolving cylinder, tracing a curve whose ordinates are values of c very much and very accurately magnified as required by conditions imposed in the previous discussion. As the openings in shutters pass the pencils of light, darkness again prevails; but the film on the rapidly spinning cylinder has secured a record of a succession of events, arranged in chronological order and extending over a period of time capable of subdivision into hundreds of parts—days, weeks, and months, relatively speaking—and yet this time, that occupied in delivery of a blow, has heretofore been characterized as synonymous, practically, with no time at all.*

The struggle with mechanical difficulties that had to be overcome in securing the stccessful working of such delicate apparatus has been a troublesome one for the writer, and he recognizes very clearly the room for further improvements. The general quality of negatives submitted herewith is not what it would have been if an accomplished photographer had been in charge of their treatment. Some excellent negatives, from the standpoint of a photographer, were produced, and attention is invited to the following enlarged reproduction of part of a time scale as a sample of what the apparatus is capable of producing:

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* See Report of General Abbot in " Submarine Mines," p. 28.

For time record not enlarged, see Fig. 2.

Some features of this print are worthy of note. Before the attainment of practically uniform velocity in plate by the method described, it was thought that the value of dt for graphical differentiation would have to be taken as the time of one-half vibration of fork. It was not practicable to produce a median line by preliminary tracing while fork was at rest, as is customary; but by fixing a grating of fine hairs, stretched taut in horizontal positions, a few hundredths of an inch in front of film and in path of tuning-fork image, the sharply defined parallel shadows were produced. Thus we have any desired number of intersecting lines instead of being restricted to one, the only disadvantage being that we must use the complete instead of the half vibration as a unit of time. For cases of ununiform velocity the great advantage of the increased number of intersecting lines lies in the fact that we are enabled to get a great number of sets of ordinates very close together, the several values for $\frac{d^2c}{dt^2}$ serving thus to check each other. The clearness with which the units of time are marked by this scale is remarkable. The adjacent downward and upward curves indicate clearly under the microscope their point of intersection; but "to make assurance doubly sure," the dense triangle in record, due to double exposure over that area, has its vertex directed to the same intersection. Contrast this with the usual stylus recore where, even with a slow fork of great amplitude, it is impossible to say exactly where intersection with median line occurs. The great advantage of the photographic record* is found in our ability to magnify, almost at will, the amplitude, without affecting distance passed over by the image in direction perpendicular to the fork's motion—this latter being a function of plate velocity alone. It is always possible, therefore, by the proper selection of magnifying ratio and of plate velocity, to cause the sides of the dense triangle, or tangents to curves at their intersection, to make an angle of exactly 45° with each other, the angle most favorable for determination of point of intersection. The actual amplitude of fork used was not over 0.03 inch, and if its record had been made mechanically it would have consisted, practically, of a right line and would have been of no value whatever.

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* We reproduce here (see plate) a copy of an actual record from No. 69, Notes on the Construction of Ordnance, Lieutenant C. B. Wheeler, Ordnance Department.

A visual contrast of the time scale here given with Figure 1 of Lieutenant Dunn's Report speaks for itself.—[Editor]

Other advantages scarcely less important are evident, viz:

A very much higher fork may be used, thus bringing, for uniform velocity of plate, the graphical value of $d\,t$ nearer the theoretical value; the nature of recording surface permits much greater accuracy in measurement of distances corresponding to the unit of time, $d\,t$, than does the comparatively rough lamp-blackened surface; the fork traces its sinusoid without performing work on recording surface.

To show general appearance of experimental curve, the following reproduction, Fig. 2, of negative No. 7 is introduced. The curve appears without change in its dimensions, *i. e.*, in reproduction no attempt is made either to enlarge or reduce. A graphical enlargment of this curve is shown in Plate II. The negative shows an *elastic recovery* of specimen, as it should, but this quantity is not found so constant in this investigation as it appears to be in static compressions. Under action of elastic resistance the weight rebounds; after second impact, it rebounds again a lesser distance, and so on until finally brought to rest. A record of these movements can be obtained by increasing time ot exposure of sun image.

Having explained how the experimental curves were obtained, it now remains to show, in accordance with the discussion herein under "General Principles," how accurately the ordinates and abscissas of these curves represent the true values of c and t in equation [1].

CALIBRATION OF FORK.

The fork used was made at Watertown Arsenal, Massachusetts, from highly tempered spring steel. It was calibrated at San Antonio Arsenal, Texas, where the negatives were made. The negatives were made during the spring of 1894 and always between the hours of 10 and 12 a. m. The temperature for that climate and season is so uniform that it was not necessary to seek any coefficient of correction in rate of fork due to change in temperature.

The fork was calibrated in the following manner: Strips 1 inch wide by 36 inches long by ¼ inch in thickness were cut from the finest grade of plate glass and coated on one face with a sensitive film. A metal clamp was made to suspend one of these strips vertically from a magnet with conical armature after the manner of those used with the Boulengé chronograph. The fork was mounted vertically and a horizontal beam of light thrown on the prong as heretofore described. With the fork at rest an initial exposure on the suspended plate gave a circular image, the diameter of which marked, when the plate was placed under the microscope of measuring instrument, the origin of fall. The fork was then set vibrating and the plate released by breaking electric curcuit. The accurate dimensions of plate and the care taken in suspending it caused its face to remain vertical during fall. If it had not done so the distance between it and lens would have changed and a variation in sharpness of definition would have been apparent in negative. On account of great sectional density of plate and low velocity attained, the effect of atmospheric resistance was inappreciable.

If it were worth while to do, this factor could easily be eliminated, in calibrating a fork by this method, since the plate could be dropped in a vacuum and the record obtained by admitting light through a glass window. The great advantage gained is due to conditions previously mentioned and to the fact that frictional resistance of guides to falling plate is removed. From the gravity record made it was only necessary to obtain by accurate measurement the distance from origin to beginning of vibrations considered, and thereafter the distance corresponding to a given number of vibrations.

The time of fall over h_0, the distance from origin to first vibration counted, is $t = \left(\frac{2h_0}{g}\right)^{1/2}$ and from origin to end of distance, h' ($h' - h_0$ covering n vibrations), $t' = \left(\frac{2h'}{g}\right)^{1/2}$. The rate of fork r, in complete vibrations per second, is then $r = \frac{n}{t' - t}$.

The larger the value of n, and therefore of $t' - t$, the less the chance for error in measurement, and the more accurate the value of r. To reduce errors in measurement the value of h_0 was taken as 0.14886 meter, the velocity of plate being sufficient at that point to permit accurate counting of vibrations, and the initial value of h' was so taken that the distance, $h' - h_0$, corresponded to 10 vibrations. By measurement the distances corresponding to 10, 20, 30, etc., up to 520 vibrations were obtained, and from formulas given the value of r was computed for each set of data.

The measured value of h_0 affected each computation, but the other data in each set were independent, and, to this extent, the tabulated values of r may be considered as independent values and used to check each other. The results are given in Table I. The accuracy in values of r should be directly proportional to the value of n, and it will be seen that the final determinations agree much closer than those computed for small values of n. No better evidence of the accuracy of this method of calibration is needed than the fact that with such a small value of n as 10, where the error in passing to rate per second is multiplied by 213.+, the computed value of r differs from the probably true one by only 0.02 of one per cent.

TABLE I.

TARAGE OF TUNING FORK. $h_0 = 0.14886$ meter.

h'	n	r	$\Delta_{\prime}(h')$	$\Delta_{\prime\prime}(h')$	h'	n	r	$\Delta_{\prime}(h')$	$\Delta_{\prime\prime}(h')$
Meter.	Vibrations.	Vibrations per second.	Meter.	Meter.	Meter.	Vibrations.	Vibrations per second.	Meter.	Meter.
.15697	10	2,136.7	.00811	. . . .	.44367	270	2,132.2	.01378	.00030
.16532	20	2,131 0	.00835	.00024	.45761	280	2,132.2	.01394	.00016
.17388	30	2,130.4	.00856	.00021	.47177	290	2,132.0	.01416	.00022
.18266	40	2,130.0	.00878	.00022	.48616	300	2,131.9	.01439	.00023
.19162	50	2,131.3	.00896	.00018	.50073	310	2,132.0	.01457	.00018
.20084	60	2,130.5	.00922	.00026	.51556	320	2,131.9	.01483	.00026
.21026	70	2,130.9	.00942	.00020	.53056	330	2,131.9	.01500	.00017
.21992	80	2,129.8	.00966	.00024	.54581	340	2,131.9	.01525	.00025
.22976	90	2,130.1	.00984	.00018	.56127	350	2,131.8	.01546	.00021
.23984	100	2,129.8	.01008	.00024	.57695	360	2,131.8	.01568	.00022
.24987	110	2,134.6	.01003	. . . .	.59282	370	2,131.8	.01587	.00019
.26039	120	2,133.9	.01052	.00049	.60894	380	2,131.7	.01612	.00025
.27104	130	2,134.4	.01165	.00013	.62526	390	2,131.6	.01632	.00020
.28201	140	2,133.5	.01107	.00048	.64181	400	2,131.5	.01655	.00023
.29315	150	2 133.3	.01114	.00007	.65852	410	2,131.6	.01671	.00016
.30451	160	2,133.2	.01136	.00022	.67555	420	2,131.4	.01703	.00032
.31610	170	2,132.7	.01159	.00023	.69272	430	2,131.5	.01717	.00014
.32788	180	2,132.7	.01178	.00019	.71012	440	2,131.5	.01740	.00023
.33988	190	2,132.7	.01200	.00022	.72772	450	2,131.5	.01780	.00040
.35212	200	2,132.4	.01224	.00024	.74558	460	2,131.4	.01786	.00006
.36457	210	2,132.2	.01245	.00021	.76362	470	2,131.4	.01804	.00018
.37719	220	2,131.9	.01262	.00017	.78192	480	2,131.3	.01830	.00026
.39005	230	2,132.4	.01286	.00024	.80036	490	2,131.4	.01844	.00014
.40314	240	2,131.2	.01309	.00023	.81907	500	2,131.3	.01871	.00027
.41641	250	2,131.4	.01327	.00018	.83799	510	2,131.3	.01892	.00021
.42989	260	2,132.5	.01348	.00021	.85707	520	2,131.3	.01908	.00016

The measurements given in column headed h' are given as they were made and without any attempt to adjust them in accordance with the known laws of gravity acceleration, so that the data in columns headed $\Delta_{\prime}$ and $\Delta_{\prime\prime}$ indicate probable location of errors in measurements. For use throughout this investigation the value of gravity acceleration g was computed for the latitude and elevation above sea level of San Antonio Arsenal, Texas (logarithm of g in inches per second $= 2.58607717$). The value of r selected was 2131.2, logarithm $= 3.3286242$. The interval of time corresponding to one complete vibration is 0.00046922 second. One-half of this, 0.00023461 second, is the value of Δt wherever this character appears in tables or on plates.

RELATION OF ORDINATES OF EXPERIMENTAL CURVE TO TRUE COMPRESSIONS.

The ratio of ordinates to compressions is an increasing function of the compression, and can be expressed by a formula involving only the two variables and constants. The formula, however, is somewhat complex in form.

A very much more satisfactory determination of the required relation was made by again resorting to photography. An arrangement was provided by means of which the downward movement of piston was controlled by a micrometer screw, and the corresponding position of sun image on sensitive surface was recorded photographically. Several "scale negatives" were thus made, and from data given by them a table was constructed giving the true compressions, with a constant difference of 0.001 inch, and the corresponding ordinates.

In all tables submitted herewith the values of compressions, and not the measured ordinates, are given, the latter having been transformed by interpolation in the table referred to. The ordinates and abscissas were measured with the "micrometer slide and microscope" belonging to Sebert velocimeter. The least reading of this micrometer is 0.00001 meter.

STUDY OF EXPERIMENTAL CURVES.

Between release and impact of falling weight we know that the relation between distance passed over H and time t is given by the equation of a parabola, $t^2 = \frac{2}{g} H$, represented in diagram as constructed on the axes OH and OT. Supposing impact to occur at the point O′, the full curve, constructed on the axes O′C and O′T′, represents the experimental curve under the assumption that the piston acquires the impact velocity of falling weight without the delay which is introduced

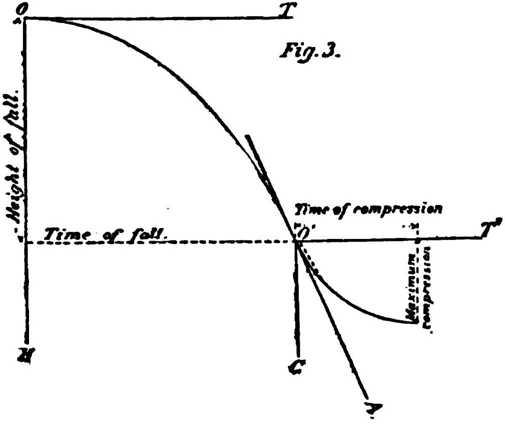

Fig. 3.

by inertia of piston, revolving mirror, and connecting masses. The two curves have the common tangent O'A. In practice, the first part of experimental curve takes the dotted position and is tangent at the origin to axis O'T, as it should be, since the piston is at rest when impact occurs.

In order to reduce shock and vibrations, which were found to interfere with accurate tracing of curve when no cushion was interposed between the hard steel surfaces of piston and impact plug, it was found necessary to place a slight thickness of rubber, about 0.05 inch, on top of piston. The compression of this rubber gave to piston the time necessary to enable it to take up smoothly the velocity of weight. Aided by elasticities of weight and piston, it caused a difference, however, in velocities of weight and piston for an appreciable time after impact and destroyed all value of experimental curve for determination, by graphical differentiation, of copper resistances over this portion of the path of compression. This explains why the graphical resistance curves, hereinafter considered, are too low for early compressions. To obtain satisfactory results for these compressions some modification in apparatus would be necessary and some improved method would have to be devised for connecting piston and revolving mirror.

It is thought best to present results of study of these curves in the following order:

1. *Resistances, as determined directly from graphical differentiation.* —In subjoined tables the data obtained from thirteen negatives are submitted. These negatives represent four sets of conditions. Negatives numbered 1, 3, 4, and 6, respectively, group No. 1, correspond to use of a 33.109-pound weight falling 13 inches. Negatives numbered 7, 8, 10, 11, and 13, respectively, group No. 2, correspond to use of same weight, 33.109 pounds, falling 15 inches. Negative numbered 21 corresponds to use of a 75.453 pound weight falling 7 inches. Negatives numbered 22, 23, and 24, respectively, group No. 3, correspond to use of a 75.453 pound weight falling 9 inches. For negatives numbered 3, 6, 7, 11, 22, and 24, respectively, extra tables are submitted, showing measured compressions and times in greater detail. Generally, the tables show two sets of ordinates, the consecutive ordinates in each set being separated by the uniform interval of time, Δt (0.00023461 second).

Plates III, IV, and V show the resistance curves plotted from data given in tables in the columns headed "Copper resistance, dynamic measure."

Negative No. 22. $H = 9$ inches; $W = 75,453$ pounds.

Time.	Designation of ordinates.	Copper compressions.	Rate of compressions per Δt	Retardation per Δt.	Mean retardation.	Copper resistance dynamic measure.	Rate of compression per Δt (graphically adjusted).	Retardation per Δt.	Retardation per Δt (graphically adjusted).	Copper resistance, dynamic measure.	Copper resistance, mean static measure.
1	2	3	4	5	6	7	8	9	10	11	12
		inch.	inch.	inch.	inch.	Lbs.	inch.	inch.	inch.	Lbs.	Lbs.
Time interval between compressions 1 a, 1 b, etc., Δt 0.0002340 + second.		.00000	*.01954				*.01954				
	1 a	.00492	.01720	. . .	. . . . . .	. . .	.01939				
	2 a	.01427	.01805	. . .	. . . . . .	. . .	.01928	.00026	.000198	704.2	
	1 b	.02212	.01914	. . .	. . . . . .	. . .	.01915	.00024			
	2 b	.03232	.01807	. . .	. . . . . .	. . .	.01897	.00031	.000360	1,280.0	1,284
	1 c	.04126	.01846	. . .	. . . . . .	. . .	.01875	.00040			
	2 c	.05039	.01833	. . .	. . . . . .	. . .	.01850	.00047	.000489	1,775.1	
	1 d	.05972	.01816	.00030			.01821	.00054			
	2 d	.06872	.01751	.00082			.01790	.00060	.000611	2,172.[illegible]	2,022
	1 e	.07788	.01701	.00115	.000598	2,126	.01754	.00067			
	2 e	.08623	.01708	.00043			.01715	.00075	.000725	2,577.[illegible]	
	1 f	.09489	.01672	00029			.01672	00082			
	2 f	.10331	.01640	.00068			.01629	.00086	.000836	2,972.5	
	1 g	.11161	.01610	.00062			.01580	.00092			
	2 g	.11971	.01543	.00097	.000084	2,987	.01531	.00098	.000939	3,338.7	2,960
	1 h	.12771	.01498	.00112			.01481	.00099			
	2 h	.13514	.01462	.00081			.01426	.00105	.001034	3,676.5	
	1 i	.14269	.01390	.00108			.01370	.00111			
	2 i	.14976	.01333	.00129			.01312	.00114	.001123	3,992.9	3,504
	1 j	.15659	.01253	.00137	.001316	4,679	.01252	.00118			
	2 j	.16309	.01185	.00148			.01190	.00122	.001201	4,270.3	
	1 k	.16912	.01117	.00136			.01127	.00125			
	2 k	.17494	.01052	.00133			.01063	.00127	.001268	4,508.5	4,068
	1 l	.18029	.01007	.00110			.00999	.00128			
	2 l	.18546	.00932	.00120	.001390	4,942	.00934	.00129	.001326	4,714.7	
	1 m	.19036	.00836	.00171			.00869	.00130			
	2 m	.19478	.00771	.00161			.00801	.00133	.001373	4,881.9	
	1 n	.19872	.00712	.00124			.00733	.00136			
	2 n	.20249	.00629	.00142			.00660	.00141	.001410	5,013.4	4,522
	1 o	20584	.00559	.00153	.001346	4,786	.00591	.00142			
	2 o	.20878	.00498	.00131			.00517	.00143	.001439	5,116.5	
	1 p	.21143	.00436	.00123			.00444	.00147			
	2 p	.21376	.00373	.00125			.00370	.00147	.001461	5,194.7	4,766
	1 q	.21579	.00296	.00140			.00206	.00148			
	2 q	.21749	.00218	.00155	.001454	5,170	.00222	.00148	.001479	5,258.7	
	1 r	.21875	.00137	.00159			.00147	.00149			
	2 r	.21967	.00070	.00148			.00072	.00150	.001491	5,301.4	
	1 s	.22012	. . . .	. . .	. . . . . .	. . .	. . . .	. . . .	.001493		
	2 s	.22037	. . . .	. . .	. . . . . .	. . .	. . . .	. . . .	.001495	5,315.6	4,928

*Impact velocity per Δt calculated.

It is evident from these plates—(1) That the probable errors in these unadjusted dynamic measures are large; (2) that their accuracy increases as we approach *maximum pressures*, as it should, since the quantity measured—retardation—then has its maximum value, and the chances for error in measuring lengths of ordinates are at a minimum, the experimental curve being practically parallel to axis of abscissas; (3) that the mean dynamic measure of *maximum* resistance is undoubtedly in excess of that given by static measure; (4) that the dynamic measures of early resistances must be rejected, since they indicate that no resistance is experienced until compression has progressed about 0.04 inch. This rejection was to be expected in view of what has been previously said on the subject of effect of interposing a thin rubber disk between piston and weight.

We are especially anxious to test the *static measure of maximum* resistance, and on this point these plates give the following data:

Group.	Compression.	Resistance, mean dynamic	Resistance, mean static	Difference, actual	Difference, crusher gauge
	Inch.	Pounds.	Pounds.	Pounds.	Lbs. per sq. inch.
Group No. 1	.1460	3,875	3,438	437	4,370
Group No. 2	.1600	4,232	3,695	537	5,370
Group No. 3	.2000	4,930	4,475	455	4,550

As a first approximation, therefore, it would seem that, when time of compression is from 0.003 to 0.004 second, the crusher gauge indications of maximum powder pressures are too low; and that the error is from 4,000 to 5000 pounds per square inch.

(To be concluded.)

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AN ALTERNATING CURRENT RANGE AND POSITION FINDER.

An account of experiments at the U. S. Artillery School, Fort Monroe, Va.

By Dr. ALBERT CUSHING CREHORE,
Assistant Professor of Physics, Dartmouth College,
AND
Dr. GEORGE OWEN SQUIER,
First Lieutenant, Third Artillery, U.S.A.,
Instructor Department of Electricity and Mines, U. S. Artillery School.

The desirability of having a range-finder using a horizontal base which may be a mile or more in length, is so generally admitted that it requires no arguments to be presented in its favor. The solution of the problem itself, namely, the finding of the ranges and positions, is one of the simplest operations of trigonometry after the angles are measured and the base is known. It is only the amount of time consumed in the process of first measuring the angles, and then making the calculations, which makes a range finder necessary at all. The chief requisite of a good range finder would seem to be quickness and reliability in action, and with that a certain necessary degree of accuracy.

The problem is however so well understood by the military world that it is a matter of common experience to meet those who have planned their own range finders, even if they have not been actually constructed. It is generally understood that the major part of the difficulty has been overcome when it becomes possible to cause an indicator of some kind to move in exact parallelism with the telescope of one of the base-end instruments a mile or more distant.

It is proposed in this paper to consider a new method, by which this problem of producing parallelism at a distance has been experimentally tried and it seems satisfactorily solved.

The perfection attained by Lieutenant Fiske in the use of the Wheatstone's bridge as applied in his Range Finder has attracted much attention, and many concede that they would not desire a better range finder than this principle affords if it were not for certain serious objections which develop only under the real test of actual practice. It is to these objections that it seems worth while giving one's careful attention and study; for if they are removed, the result seems certain. Among some of the objections may be mentioned the number of adjustments necessary before operating, the difficulty which most operators would meet in repairing any part which might get out of order, the sliding electrical contacts, and the necessity for a low resistance line between the two distant stations.

In comparatively recent years the alternating current in electricity has received a tremendous commercial development, which has been at least an incentive to the thorough study of the various phenomena connected with it. These phenomena include many additional things over and above what one meets in direct current flow, and some of them have such an importance that the alternating current is finding its way continually to new practical applications for which the direct current is not adapted. In alternating current work the "inductance" of the line should be known as well as its resistance; the inductance giving rise to a "reactance" which in some ways has the same effect as a resistance. In fact this reactance may be and often is the factor which controls the current, and is much more important than the resistance of the circuit itself. This is one of the phenomena which usually surprises one trained in the old school of direct current electricity, where the ohm played the all important part.

It is the use of the alternating current with the Wheatstone's bridge to obtain parallelism, which is one of the essential differences in the method proposed from those already used. Nearly all the difficulties met with before seem to vanish naturally; the instrument need not be extremely delicate and difficult of adjustment, but may even be roughly handled without serious injury. The resistance of the wires is of little importance, and the line resistance need not be low; for example the iron telegraph wires already laid between the two stations where the base-end instruments are situated at Fort Monroe, Va., were used without alteration in these experiments, the distance being 1922.305 yards.

Perhaps the point most in its favor is the fact that all the wires may be permanently laid and encased, never to be touched, since there are to be no "sliding contacts" where a contact moves along a "perfectly uniform" wire, one whose length is proportional to its electrical resistance. The use of these sliding contacts is avoided in the present instance by causing a bundle of soft iron wires to move into and out from a solenoid. In this manner the reactance of the circuit is varied, and not the resistance. It is the reactance, and not the resistance, which plays the more important part in governing the current, and here there is a means of varying the reactance without altering the electrical circuit at all, simply through the influence of the iron in the solenoid, which is transmitted through the ether.

METHOD OF EXPERIMENT.

In Fig. 1 is shown the ordinary arrangement of the circuits of a Wheatstone's Bridge supposed to contain in the branch numbered 6 a source of alternating E. M. F., and in the conjugate branch numbered 5 a mil-ammeter for detecting the presence of an alternating current. The branches 1, 2, 3, and 4 are supposed to contain coils with inductance. A disposition of these circuits, which makes it more evident how they may be used in an actual case is illustrated in Fig. 2, where the letters and numbers correspond. In this Figure the group of circuits and apparatus near Station H, is located at one of the observing stations, and that marked Station A at the other, while the generator may be at any convenient place, in the present instance at the Electrical Laboratory. A single line runs from the laboratory to the point *A*, Station H, which corresponds with circuit 6, Fig. 1. At *A* it divides along the branches 1 and 2, which are each stationary coils containing inductance, and arrives at the points *C* and *D*, between which points the galvanometer is inserted making branch 5. From *D* the circuit first passes around the coil which is to contain the movable iron core, and thence along the line to the point *B* at Station A, which is connected to the ground or the return. From *C*, the circuit passes immediately to the line running to Station A, and thence around the coil with the movable iron core and to *B*, the return.

The method of operation is as follows: The inductances of circuits 1 and 2 are fixed and constant, preferably approximately equal. If the iron core of circuit 3 is set in a certain position within the solenoid, then there is only one position of the core in 4, in one end of the coil, which will bring the galvanometer indication to zero. A motion of the cores is communicated to the telescopes or indicators by suspending the core vertically within its coil by means of a steel ribbon, which passes up over a pulley having a horizontal axis, and thence around a large circle with a vertical axis upon which the indicator is mounted. In practice the core is movéd by turning the large circle.

If the coils 1 and 2 with their cores are made exactly alike and also the coils and cores of 3 and 4, it is evident that the positions of the cores 3 and 4 will always be the same for zero galvanometer current. Hence if the large horizontal wheels are alike, the telescopes or indicators will always remain parallel for a zero galvanometer reading. The objection may be raised that it is impossible to make the coils and cores exactly alike, which must be admitted. A further consideration however will show that this condition of equality is not a necessary one, though desirable; for even though the electrical parts are exactly alike, the motion of the horizontal circles may be altered at pleasure by slightly changing the shape of the wheel from a true circle, or by making a cam of it. This plan is not proposed, however, as it is found in practice that the motions are alike within the error of setting by the galvanometer, even though the coils are only approximately alike. This cause in other words does not seem to be the largest source of error.

APPARATUS USED.

The preliminary experiments were made in the laboratory of the U. S. Artillery School during July and August, 1896, to determine first roughly whether the plan would succeed. This apparatus is shown in the view Fig. 3, where may be seen resting upon a high table two sets of instruments, practically alike.

The coil *AC* (1) corresponding to circuit (1) Fig. 1 rests upon the table and has a bundle of iron wires for its core. The coil *AD* (2) is a similar coil corresponding to circuit 2. *CB* (3) is a coil screwed to a board in the vertical position, having an iron core I attached to a flexible steel ribbon *R* which passes over the pulley *P* and thence around the horizontal wheel *T*. This coil corresponds to circuit (3) Fig. 1 and the similar vertical coil *DB* (4) to circuit (4).

THE GALVANOMETER.

The instrument needed as a galvanometer to be used for zero readings must be one suited to indicate alternating currents of small magnitude. These instruments are not among those which are manufactured for commercial purposes at present, so that resort was made to the nearest thing available. A telephone was tried and worked fairly well, but the ear does not seem to be so good an organ to use as the eye, and finally a universal galvanometer adapted to serve as a Siemens' dynamometer gave much better results. When a range finder is constructed, a special instrument will be made adapted to the purpose, which will probably increase the accuracy of the results.

The deflection of the coil of the dynamometer with alternating currents is always towards one side, so that in practice the needle is brought down to its minimum reading instead of a zero reading. This minimum is not always the zero reading, though very near to it; for the current never falls exactly to zero unless the wave of current flow is exactly harmonic.

METHOD OF TESTING FOR PARALLELISM.

An optical method was employed in the laboratory in making the test for parallelism, similar to that used in the well known Sextant instrument. Two plane mirrors *M* and *M'*, Fig. 3, were mounted one on the rotating table of each instrument. The diagram Fig. 4 illustrates the mode of operation. The observer at *E* looks directly at a distant object *O* through the laboratory window, and sees the same object by reflection in the mirrors *M* and *M'*, then brings the objects into coincidence by rotating one of the mirrors. The mirrors are parallel when the objects coinside, and in this position they are clamped while the galvanometer is standing at zero. After this adjustment is made one of the horizontal wheels is turned together with its mirror, which operation moves the iron core either up or down. This operation throws the galvanometer out of position, and it will not return until the other wheel and mirror with its iron core are moved a corresponding amount. The galvanometer then again indicates zero, and it is also found that the object and the image seen in the mirrors are again brought nearly into coincidence.

In this trial the optical test was more severe and accurate than the galvanometer indication, but the coincidence was so close and parallelism so nearly attained that it was decided to give the method a more thorough test by instruments where these small differences, the errors, could be measured. A motion of the iron core through a distance of one one-hundredth of an inch made a perceptible difference in the galvanometer indication.

An inspection of the base-end instruments already in use at Fort Monroe, suggested that the apparatus already made might be used in conjunction with those instruments as a kind of attachment without making any alteration whatever. Fortunately this was made possible because there happened to be a slight elevation of the rim of the circle of the base-end telescope, just high enough to admit of winding around it the steel ribbon already mentioned. This rim is a circle 16 inches in diameter, and revolves in a circle of the same size made to receive it. The bearing circle is imbedded in cement, and supported upon a brick pier built up from the sand of the beach.

In Fig. 5 is seen a view of this base-end instrument situated at the station known as "Station H." This station is a small wooden structure situated at the water's edge upon the sandy beach. The brick pier is built up from the sand, and one of the instruments shown in Fig. 3 is seen here fastened to the side of the pier by the iron bolts *BB*. The coil *DB* (4) and core *I'* with pully *P'* having the ribbon *R'* passing around it are the same as those seen in Fig. 3. The ribbon then passes directly around the 16-inch circle and is clamped to it. The telescope carries with it upon an arm the vernier, which moves inside the rim of the graduated circle. The circle itself revolves in the outer bearing circle already mentioned, and either telescope or circle may be clamped to its bearing.

Fig. 6 shows a view of the other instrument which was attached in a similar manner to the pier at the station known as "Station A," also situated upon the beach at the water's edge; the distance between the two stations being 1922.305 yards, or 1757.6 meters.

The wiring is shown in Fig. 2 where the alternator *M* is in the laboratory, from which a single wire runs to Station H, a distance of 810 yards. Two wires run from Station H to Station A, a distance of 1922.305 yards, and a ground return is used for both.

Station A is 1868 yards from the laboratory. It will be seen that it is not necessary to have two lines run between Stations H and A; for the line marked *DB* (4) simply goes from H to A to be grounded. It may as well be so grounded at Station H, and the reason for using it in the present instance was merely the practical one, that if it were not used a substitute coil would have had to be made which would exactly simulate the line, as the two lines 3 and 4 should have the same impedance. The easiest way to accomplish this was to use the two lines already laid.

THE MANNER OF USING THE BASE-END INSTRUMENTS.

The only vernier upon the instrument is attached to the telescope and revolves with it upon the inside of the graduated circle. It became necessary, in using the instrument as intended, to provide some way of reading the angle through which the outside circle turns. As ordinarily used this outside circle remains at rest, and the telescope alone with the vernier moves, but in the present instance the large circle is required to move in order to wind up the steel ribbon.

To overcome this difficulty the following plan was adopted by which the inside vernier became available.

Some distant object is selected by each observer, not necessarily the same object for both, though as a matter of fact the same object happened to be used on account of its convenience. It was the pole on the top of "Bug" light, a light house 6500 yds. from Station H. While the telescopes are kept set upon this object, the coils are raised or lowered in their solenoids by revolving the outer circle without the telescope, until the galvanometer indicates a minimum. In this position the telescopes are clamped, that is, while they are each pointing towards Bug Light, and the galvanometer stands at a minimum. The reading of the vernier upon its circle is then recorded. The circle is divided into half degrees, and the vernier reads to minutes. Next, the telescope at station A is turned without its circle through any desired angle, say ten degrees, for example, and clamped again. The telescope and circle with the iron core are then revolved together until the telescope again points to Bug Light. By this method the large circle can be revolved through any given angle by simply reading the vernier already provided. The second observer next moves his telescope with circle and iron core until the galvanometer indicates a minimum, and clamps the circle. The telescope is then unclamped and turned back to Bug light, and the reading of the vernier recorded. If the instrument works without error this angle should be the same as that of the first instrument, namely ten degrees. The differences in the readings of the two instruments indicate the errors.

The range through which the telescopes could turn was about 125 degrees, and was limited only by the length of coil and iron core, which is a matter that may always be arranged so as to admit of as wide a field as desirable. In these trials it was found that the galvanometer would indicate when the telescope had moved over the same angles within the error of setting. Inasmuch as the other errors are smaller than the error of setting, therefore it will only be necessary to give the error of setting. By the error of setting is meant the error which is made by the observer at station H in trying to set his telescope corresponding to that at station A by means of the galvanometer observations alone. An example giving the readings for twenty independent settings made by the observer at station H for one given setting of the telescope at station A will make this more clear. The vernier at station A was set to read exactly 180 degrees, and twenty observations were made at station H to set the telescope by the galvanometer indication, moving the telescope out of adjustment each time to make sure of independent settings, according to the following table :

No.	Reading.	Difference from the mean.	Difference squared.
No. 1	14° 49′	6.75	45.5625
2	" 39	3.25	10.5625
3	" 46	3.75	14.0625
4	" 40	2.25	5.0625
5	" 38	4.25	18.0625
6	" 42	.25	.0625
7	" 42	.25	.0625
8	" 50	7.75	60.0625
9	" 37	5.25	27.5625
10	" 37	5.25	27.5625
11	" 39	3.25	10.5625
12	" 41	1.25	1.5625
13	" 42	.25	.0625
14	" 41	1.25	1.5625
15	" 42	.25	.0625
16	" 42	.25	.0625
17	" 42	.25	.0625
18	" 43	.75	.5625
19	" 42	.25	.0625
20	" 51	8.75	76.5625
Mean	14° 42′.25	2′.775	299.7500 = $\Sigma e^2 = s$

Mean $e = 2'.775$

Mean value $= 14° 42.'25$

Probable error of result $= .674 \sqrt{\frac{s}{n(n-1)}} = 0'.598$

Probable error of single observation $= .674 \sqrt{\frac{s}{n-1}} = 2.'67$.

It is seen by the table that the mean error for twenty observations is 2.775 minutes of arc and the greatest error is 8.75 minutes. Remembering that a minute is about the angle subtended by one foot and a half, or half a yard at a distance of a mile, this mean error of 2.775 minutes is equivalent to 1.39 yards at the distance of a mile, or 7.9 yards at the distance of 10,000 yards, which is at present about the limit of firing distance, being equal to 5.68 miles. An instrument which will locate a target within 8 yards at a distance of 10,000 yards comes within the limits of requirement for a good range finder. The probable error of a single observation is still smaller than the mean, being only 2.67 minutes. Perhaps the greatest error is of more importance than the mean, for when the greatest error is well within the required limits, the location of the target is more certain. In the present instance the greatest error of 8.75 minutes corresponds to about 25 yards in 10,000.

The erroneous conclusion must not be drawn from the above that this is the limit of accuracy attainable with this form of instrument. The above result exceeded the experimenters' expectations as to accuracy, it being understood that whatever accuracy was attained by this instrument might be increased with certainty three or four fold. For example the diameter of the large circle was only 16 inches, and by doubling this, the accuracy is immediately increased two-fold. It will be noted that only one size and length of coils and cores have yet been tried, being those which were first constructed for the purpose, in combination with base-end instruments not constructed with direct reference to this object. The error of setting is not the same for all positions of the iron core, being less when it approaches the center of the coil than it is further out, and less again when it is too far out, so that there is a point of maximum sensibility. The range through which the indication is sufficienly sensitive is however long enough to cover the desired field.

DISCUSSION OF THE CURRENTS IN THE BRANCHES OF A WHEATSTONE'S BRIDGE, WHERE EACH BRANCH CONTAINS RESISTANCE AND INDUCTANCE, AND THERE IS AN HARMONIC IMPRESSED ELECTROMOTIVE FORCE.

The complete discussion of the currents flowing in the branches of a Wheatstone's Bridge, with a simple harmonic E.M.F., leads by the analytical method to equations which are too cumbersome to be of much practical use. For instance, by the direct method there would be formed as many differential equations as there are branches to the bridge, namely six, and these six simultaneous equations would by a process of elimination lead to a single differential equation of the sixth order, the solution of which would give the current in any desired branch. The practical obstacles in the way of finding the single differential equation from the six simultaneous equations, and after that obtaining its solution, are so great that if the same results can be obtained in a simpler way it would be welcomed. Having once written down the equations of current flow in the branches, it is a comparatively easy matter to determine the conditions for zero current in the galvanometer.

It happens that for this important particular case of zero current in the galvanometer, there is a very simple way of determining these conditions for an harmonic E.M.F. Either the analytical or the graphical method will give the result, but the graphical method apparently gives so much more at the same time that it is preferred. The use of these graphical methods is so general and becoming now so well understood, that it is not considered desirable to repeat here the propositions which logically precede a complete understanding of the present discussion. A reference is made for those who desire to pursue the subject more thoroughly, to the graphical treatment* of Alternating Currents.

Referring to Fig. 1, let the six branches of the bridge be denoted by the numbers 1 to 6, and denote the resistances and inductances of the branches by the letters

R_1, R_2, R_3, R_4, R_5, R_6, for resistances

and

L_1, L_2, L_3, L_4, L_5, L_6, for inductances.

Let n denote the number of complete periods per second of the E.M.F. of the generator, and let T be the time of one period. Then $n = 1/T$. If a point move uniformly around the circumference of a circle, then the projection of that point upon any diameter has simple harmonic motion, and the angular velocity ω of the point on the circumference is $2\pi/T$ or $2\pi n$.

In Fig. 7, let the line OA represent the impressed E.M.F., E, at the terminals AB, Fig. 1, of the Wheatstone's Bridge. Since in the present discussion no current flows in the galvanometer circuit, then no change will take place in the other currents which are flowing, if the galvanometer circuit is broken. Imagine it to be so broken, and we have merely the case of a divided circuit of two branches, each branch containing two coils with impedance. To find the currents in each branch independently, a rule analogous to Ohm's law is applied. This states that the current I is equal to the E. M. F. divided by the impedance, or,

$$(1) \qquad I_{1,3} = \frac{E}{\Sigma J} = \frac{E}{\sqrt{(\Sigma R)^2 + (\Sigma L\,\omega)^2}}.$$

The angle by which this current lags behind the impressed E.M.F., OA, is given by the equation;

$$(2) \qquad \tan\theta_{1,3} = \frac{\Sigma_{1,3}\, L\,\omega}{\Sigma_{1,3}\, R}.$$

The subscript 1,3 refers to the current in the branches (1) and (3).

In Fig. 7, make the angle AOC equal to arc tan $\theta_{1,3}$ of equation (2), and this determines the direction of the current $I_{1,3}$. Then upon the line so drawn take the point D so that OD represents in length the number of units contained in $I_{1.3}$ equation (1). The line OD then represents the current flowing in the circuits (1) and (3). A similar calculation may be made for the branch (2) and (4), and another current OD' drawn upon the diagram. Having determined the two branch currents OD and OD', the current in the main line is the geometrical sum of these currents, represented by the line OR.

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* Bedell and Crehore on "Alternating Currents" Part II, W. J. Johnston Company, New York. Bedell on the "Principles of the Transformer." Mac Millan & Company.

The potential difference between the points C and D of the bridge is by hypothesis zero, and that between the terminals A and B is E. It remains to find the potential difference between the points A and C, A and D, C and B, and D and B. Draw a perpendicular from A upon the line OD, then OC represents the whole of that component of the total E.M.F., E, which goes to overcome the resistance of the two circuits (1) and (3). This E.M.F. following Ohm's law is equal to the product of the current and resistance. Hence $OC = (R_1 + R_3)\, I_{1.3}$. Similarly a point C' may be found upon the line OD', and $OC' = (R_2 + R_4)\, I_{2.4}$. These lines OC and OC' may then be divided into two parts proportional to the resistances R_1, R_3 and R_2, R_4. Such a division gives the points H on OC, and K on OC', so that $OH = R_1\, I_{1.3}$; $HC = R_3\, I_{1.3}$; $OK = R_2\, I_{2.4}$ and $KC' = R_4\, I_{2.4}$.

Just as OC represents the component of the total E. M. F., E, which is in the direction of the current, and may be called the "power E.M.F.," so CA represents that component which is at right angles to the current, and is called the "reactive E.M.F." This part of the total E.M.F. is due to the presence of the magnetic field in the circuits, and it may be divided up in a similar manner into parts which represent the separate effects of the coils (1), (2), (3) and (4). The line CA is equal to $(\Sigma_{1.3}\, L\omega)\, I_{1.3}$ and may be divided at M into the two parts $CM = L_1\, \omega\, I_{13}$ and $MA = L_3\, \omega\, I_{1.3}$. Similarly $C'A$ is divided at N into two parts $C'N = L_2\, \omega\, I_{2.4}$ and $NA = L_4\, \omega\, I_{2.4}$.

To find the potential difference at the terminals of any coil as AC, Fig. 1, we need only combine the componont E. M. F's. for that coil, one in the direction of the current and the other at right angles to it. This gives for circuit AC (1) the line $OH = R_1\, I_{1.3}$ in the direction of the current, and $HP = L_1\, \omega\, I_{1.3}$ at right angles to the current, to be geometrically added together, making the resultant OP the potential difference at the terminals of the coil AC (1). A similar process gives OQ for circuit AD (2), and PA for CB (3), and QA for DB (4).

Fig. 7 is drawn to represent the case of a divided circuit, and by joining a circuit across between the points C and D becomes the Wheatstone's Bridge. If such a connection were made, the arrangement of the lines as drawn would be disturbed by the current which flows across the new circuit. Before the connection is made however, it is evident that the potential difference is represented by the line PQ in the Figure; for the closed circuit ACD Fig. 1 contains no impressed E.M.F. Hence the total fall of potential around the circuit must be equal to zero. The three E.M.F's in these branches must therefore form a triangle, and as the E.M.F's. OP and OQ are determined, it follows that the E.M.F. PQ must be that between the terminals CD (5).

We then have:

The condition for no current in the galvanometer is that the points P and Q in the diagram shall coincide, or that the line PQ shall be zero.

In Fig. 8 is represented another diagram constructed like Fig. 7, except that the points P and Q are brought into coincidence at P. The condition that P and Q shall coincide, by referring to the Figure, and observing that the points H and K lie upon a semi-circle having OP as diameter, while M and N lie upon one having PA as diameter, may be expressed by the equations derived from the right triangles OHP and OKP, viz:

$$OP^2 = OH^2 + HP^2 = OK^2 + KP^2$$

(3) or $$I_{1,3}^2 (R_1^2 + L_1^2 \omega^2) = I_{2,4}^2 (R_2^2 + L_2^2 \omega^2).$$

Again

$$PA^2 = PM^2 + MA^2 = PN^2 + NA^2$$

(4) or $$I_{1,3}^2 (R_3^2 + L_3^2 \omega^2) = I_{2,4}^2 (R_4^2 + L_4^2 \omega^2).$$

Dividing equation (3) by (4), member for member, we obtain

(5) $$\frac{R_1^2 + L_1^2 \omega^2}{R_3^2 + L_3^2 \omega^2} = \frac{R_2^2 + L_2^2 \omega^2}{R_4^2 + L_4^2 \omega^2},$$

or denoting the impedances of the branches by J_1, J_2, J_3 and J_4, respectively, and remembering that $J_1 = \sqrt{R_1^2 + L_1^2 \omega^2}$; $J_2 =$ &c., we have

(6) $$\frac{J_1}{J_3} = \frac{J_2}{J_4},$$

as the necessary condition for zero current in the galvanometer.

This equation asserts:

When an harmonic electromotive force is impressed upon one of the branches of a Wheatstone's bridge, a galvanometer in the conjugate branch of the bridge can only indicate zero current when the impedances of the remaining four branches of the bridge form a simple proportion.

This is entirely analogous to the well known condition when the direct current is used in the Wheatstone's Bridge, namely, that the resistances in the branches of the bridge shall form a proportion.

Another expression which the diagram makes apparent, and will be useful to note, is that derived from the triangles OAC and OAC' inscribed in the semi-circle. These give

$$OA^2 = OC^2 + CA^2 = OC'^2 + C'A^2,$$

or

$$E^2 = (R_1 I_{1.3} + R_3 I_{1.3})^2 + (L_1 \omega I_{1.3} + L_3 \omega I_{1.3})^2 = (R_2 I_{2.4} + R_4 I_{2.4})^2 + (L_2 \omega I_{2.4} + L_4 \omega I_{2.4})^2,$$

$$(7) \qquad E^2 = I_{1,3}^2 \Big[(R_1 + R_3)^2 + (L_1 + L_3)^2 \omega^2 \Big] = I_{2.4}^2 \Big[(R_2 + R_4)^2 + (L_2 + L_4)^2 \omega^2 \Big].$$

Adding (3) and (4), we have

$$(8) \qquad I_{1,3}^2 \Big[R_1^2 + L_1^2 \omega^2 + R_3^2 + L_3^2 \omega^2 \Big] = I_{2,4}^2 \Big[R_2^2 + L_2^2 \omega^2 + R_4^2 + L_4^2 \omega^2 \Big].$$

Subtracting (8) from (7), we have

$$(9) \qquad I_{1,3}^2 \Big[R_1 R_3 + L_1 L_3 \omega^2 \Big] = I_{2,4}^2 \Big[R_2 R_4 + L_2 L_4 \omega^2 \Big].$$

This may be written so as to express the ratio of the currents in the branches, as

$$(10) \qquad \frac{I_{1.3}^2}{I_{2.4}^2} = \frac{R_2 R_4 + L_2 L_4 \omega^2}{R_1 R_3 + L_1 L_3 \omega^2}.$$

Equations (3) and (4) may also be so written as to express this ratio, and we have

$$(11) \qquad \frac{I_{1,3}^2}{I_{2,4}^2} = \frac{R_2^2 + L_2^2 \omega^2}{R_1^2 + L_1^2 \omega^2} = \frac{R_4^2 + L_4^2 \omega^2}{R_3^2 + L_3^2 \omega^2} = \frac{R_2 R_4 + L_2 L_4 \omega^2}{R_1 R_3 + L_1 L_3 \omega^2} = \frac{J_2^2}{J_1} = \frac{J_4^2}{J_3^2}.$$

In regard to the problem before us, namely, the application of this Wheatstone's Bridge to the range-finder, the resistances R_1, R_2, R_3, and R_4 as used are each permanently fixed in position once for all never to be moved. This meets any objection to the use of sliding contacts over uniform wires, and moreover the resistances are made small as compared with the inductances so that any variation which might happen from any cause, such as temperature, would have so much the less effect. The balance of the Bridge as used is rather between the reactances than the resistances. Moreover the inductances of the two branches *AC* (1) and *AD* (2) Figs. 1, 2, and 3 were also made constant, so that of the entire eight quantities R_1, R_2, R_3, R_4, L_1, L_2, L_3 and L_4, six of them are constant and only two, namely L_3 and L_4, are variable.

It is possible therefore to calculate from the preceding conditions the value of L_3 for every value of L_4 which will produce zero current; for example if we denote the reactance $L_3\,\omega$ by x and the reactance $L_4\,\omega$ by y, then equation (11) may be written in the form

$$k = \frac{m + y^2}{n + x^2} = \frac{p + qy}{r + sx}, \tag{12}$$

where k is a constant equal to $\frac{I_{1,3}^2}{I_{2,4}^2} = \frac{R_2^2 + L_2^2\,\omega^2}{R_1^2 + L_1^2\,\omega_4}$, and $m = R_4^2$; $n = R_3^2$; $p = R_2 R_4$; $q = L_2\,\omega$; $r = R_1\,R_3$; and $s = L_1\,\omega$.

Equation (12) may be reduced to

$$qx^2y - sxy^2 + px^2 - ry^2 + ex + fy + g = 0, \tag{13}$$

where

$$e = -ms = -R_4^2 L_1\,\omega\,;\ f = qn = R_3^2 L_2\,\omega\,;$$

and

$$g = pn - mr = R_2 R_4 R_3^2 - R_1 R_3 R_4^2.$$

This is evidently an equation of the third degree between two variables, the reactances of the variable coils at the two stations in the range finder problem; and it enables one to find that value of the inductance at the distant station, which will just balance any inductance at the other station. This equation is of use in calculating points of maximum sensitiveness, and it also shows other useful relations. For instance, in the present case the resistances R_1 and R_2 are made approximately equal as well as the inductances L_1 and L_2. The equation shows that not only is it necessary for the inductances of the other two branches (3) and (4) to be equal for zero current, but the resistances of those branches must also be equal. Substituting $x = y$ in equation (13) satisfies the equation if $R_1 = R_2$; $R_3 = R_4$; and $L_3 = L_4$.

This point may be clearly seen in the diagrams. In Fig. 8, in which the points *P* and *Q* of Fig. 7 were merely brought into coincidence, it will be seen that

$$\tan POH = \frac{L_1\omega}{R_1}, \tag{14}$$

$$\tan POK = \frac{L_2\omega}{R_2}, \tag{15}$$

$$\tan APM = \frac{L_3\omega}{R_3}, \tag{16}$$

$$\tan APN = \frac{L_4\omega}{R_4}. \tag{17}$$

By making $R_1 = R_2$ and $L_1 = L_2$ we reduce (14) and (15) to equality, so that, as the angles are the same, the points *H* and *K* are brought into coincidence at *H*, Fig. 9, upon their circle *OHKP*. Since the points *C* and *C'*, Fig. 8, lie in the lines *OHC* and *OKC'* as well as upon the circle *OCC'A* they are also brought into coincidence at *C*, Fig. 9. As the points *M* and *N* lie both upon the lines *AMC* and *ANC* and the circle *ANMP*, these points are also brought into coincidence at *M*, Fig. 9. By equation (11) the branch currents *OD* and *OD'* are made equal by these conditions, so that the points *D* and *D'* coincide in the figure, while $OR = 2\,OD$, and has the same direction.

VARIATION DIAGRAMS.

In Fig. 9 are represented the currents and potentials for a single value of the resistances and inductances only. If different inductances L_1 and L_2 are used, while all the other qualities remain the same, the diagram would be completely altered, and it is very desirable to know how the various points in the diagram move with a gradual change in the two inductances, provided always the galvanometer remains at zero. Fig. 10 illustrates this variation, and shows that the point *P* moves along the circle *AZPY* in the direction of the arrow as the inductances L_1 and L_2 increase. The point *M* moves upon the circle *XMA* in the direction of the arrow as the inductances increase. The points *H*, *C*, and *D* move along the circles *ZHO*, *ACO*, and *DO* as the inductances increase. This diagram enables one to draw the true diagram for any value of the inductances. The points do not move on the dotted parts of the circles, but are limited to the heavy portions. The diameter *AX* is at right angles to *OA*, and the line *PM* produced passes through the point *X*. The triangle *APM* is similar to itself in all positions, for the angle at *P* must be constant and equal to arc tan $L_3\omega/R_3$. Hence the diameter *AY* makes an angle *XAY* with *AX*, equal to *MAP*. The point *C* always lies on the semi-circumference *OCA*. Hence the points *H* and *D* move on similar circles, their distances from *O* always being proportional to *OC*.

THE CONSTANTS OF THE CIRCUITS AS USED IN THE EXPERIMENTS.

Four coils were wound nearly alike upon four similar spools.

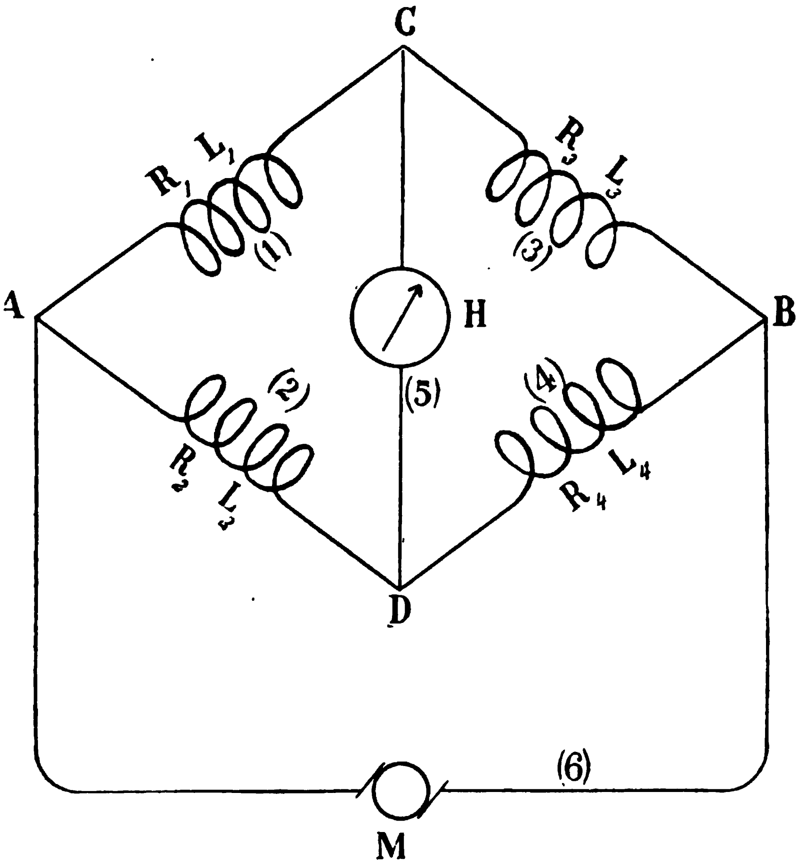

FIGURE 1.

General Diagram of Wheatstone's Bridge.

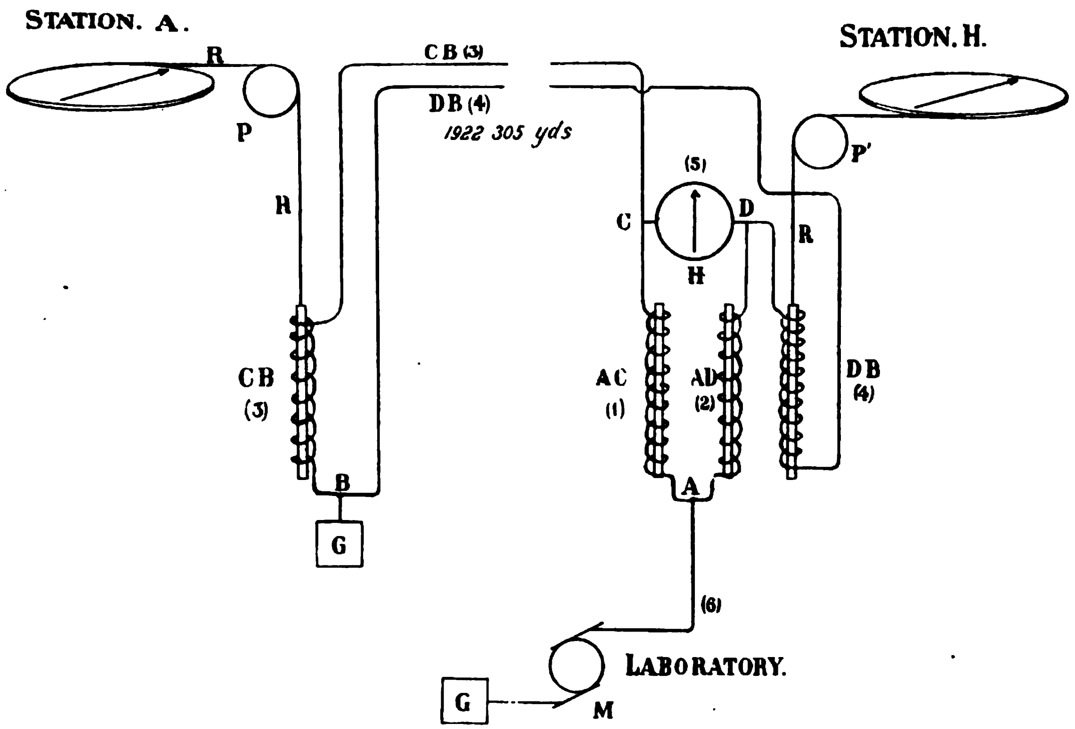

FIGURE 2.

General arrangement of electrical circuits for Alternating Current Range Finder Experiments.

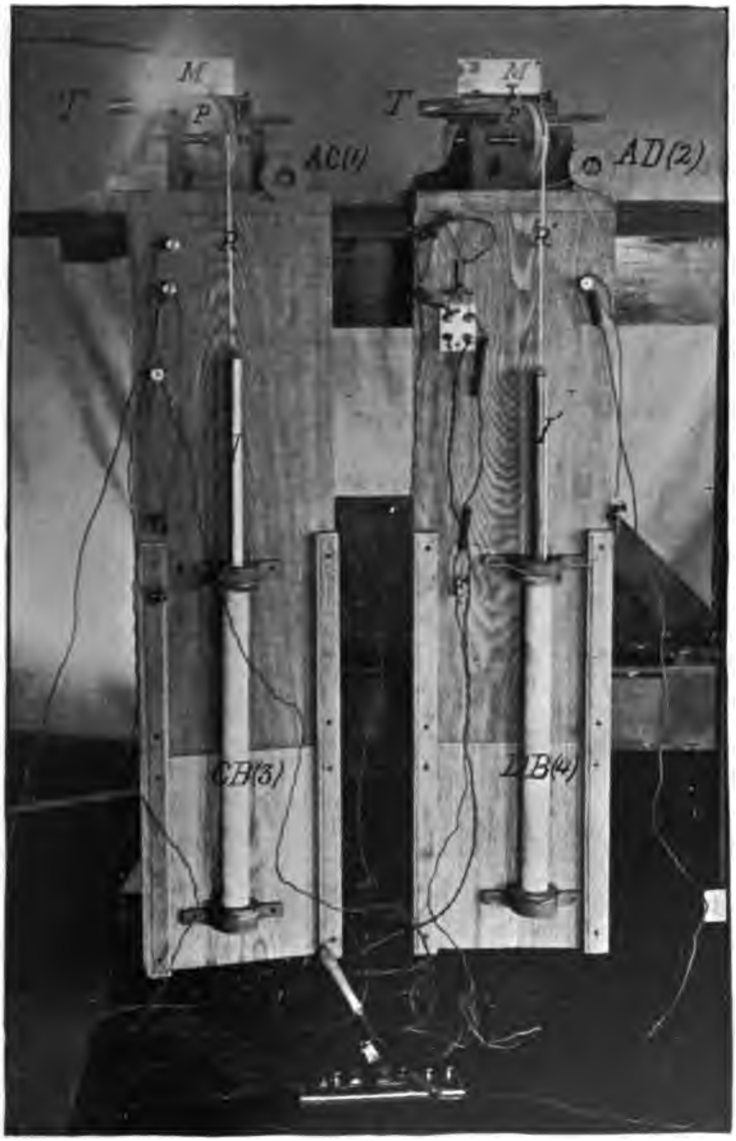

FIGURE 3.

Laboratory Apparatus for testing Alternating Current Range Finder
Electrical Laboratory, U. S. Artillery School.

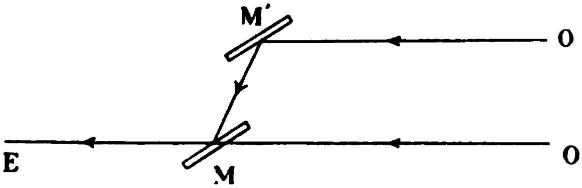

FIGURE 4.

Illustrating method of testing for parallelism similar to the sextant instrument.

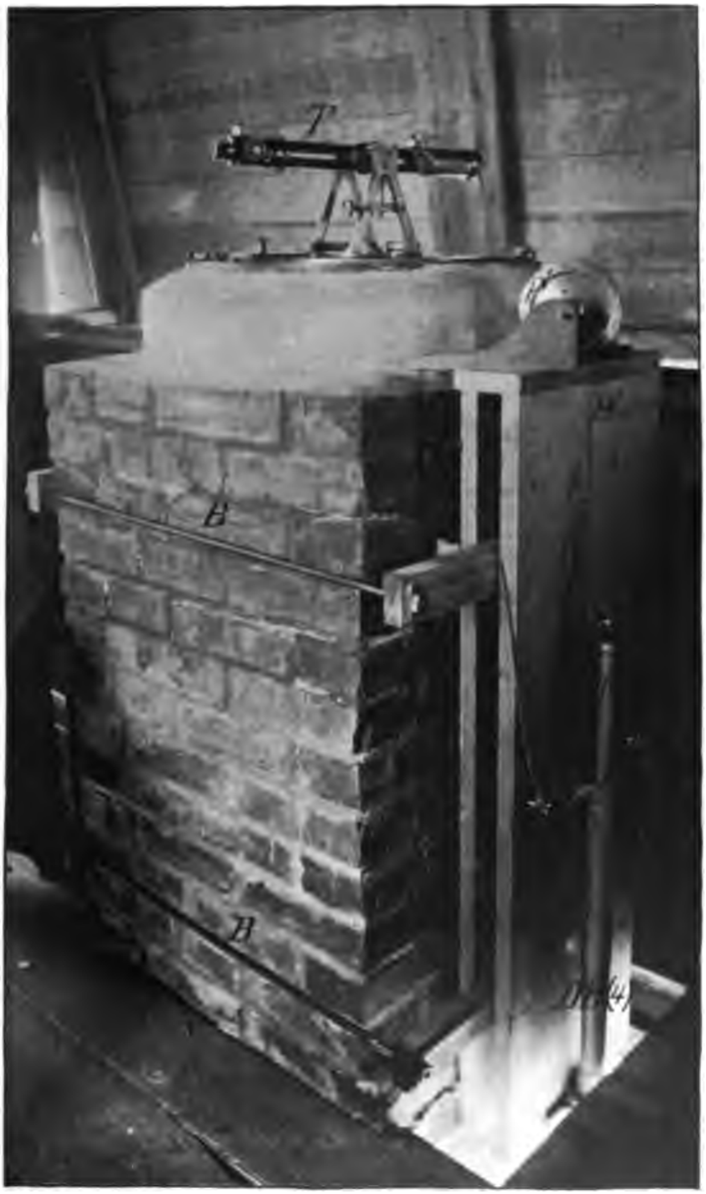

FIGURE 5.

Azimuth Instrument, Station "H", Fort Monroe, Va., showing attachment for Alternating Current Range Finder Experiments.

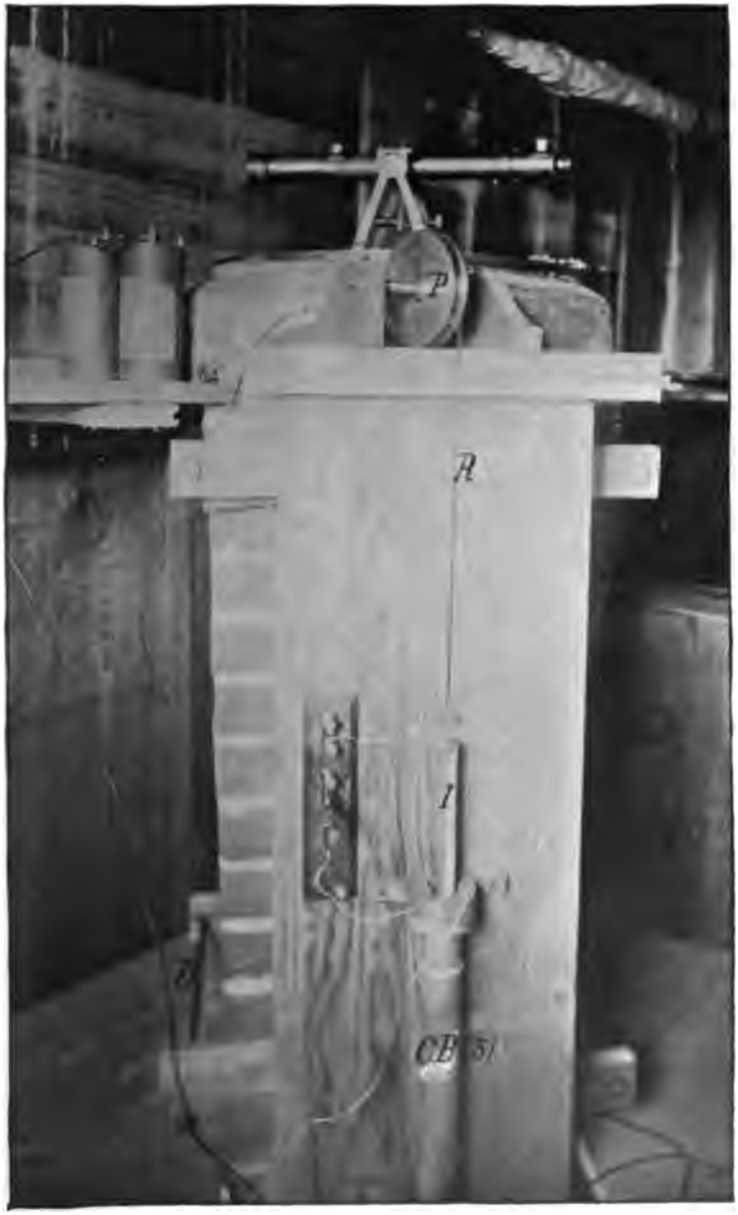

FIGURE 6.

Azimuth Instrument, Station "A". Fort Monroe, Va., showing attachment for Alternating Current Range Finder Experiments.

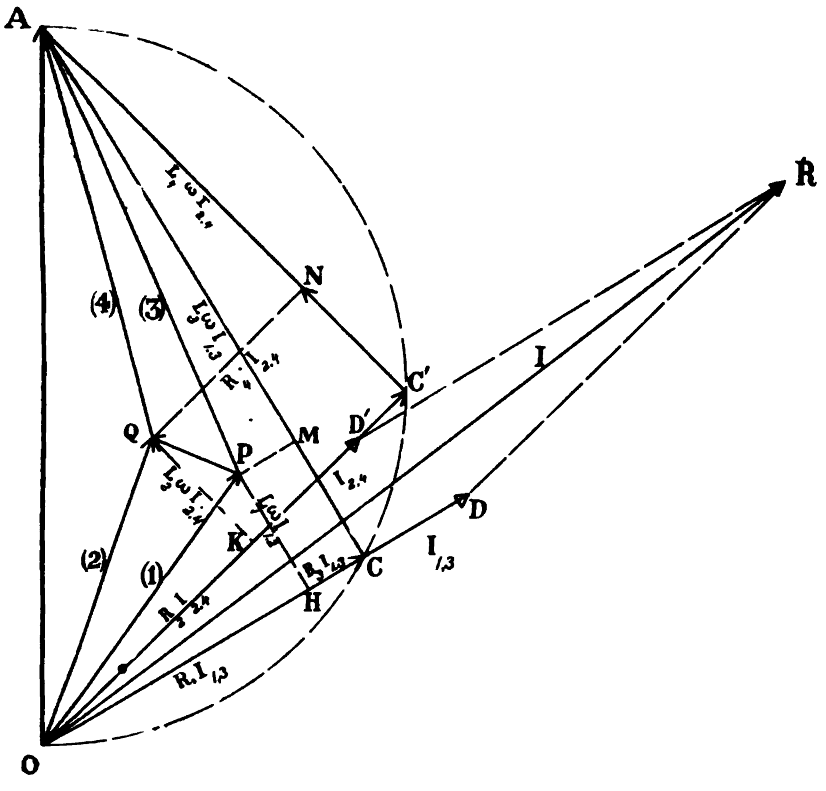

FIGURE 7.

General diagram, illustrating the currents and potential differences in the two branches of a divided circuit, each branch containing two coils with impedance; and showing the condition for zero current in the galvanometer of a Wheatstone's Bridge.

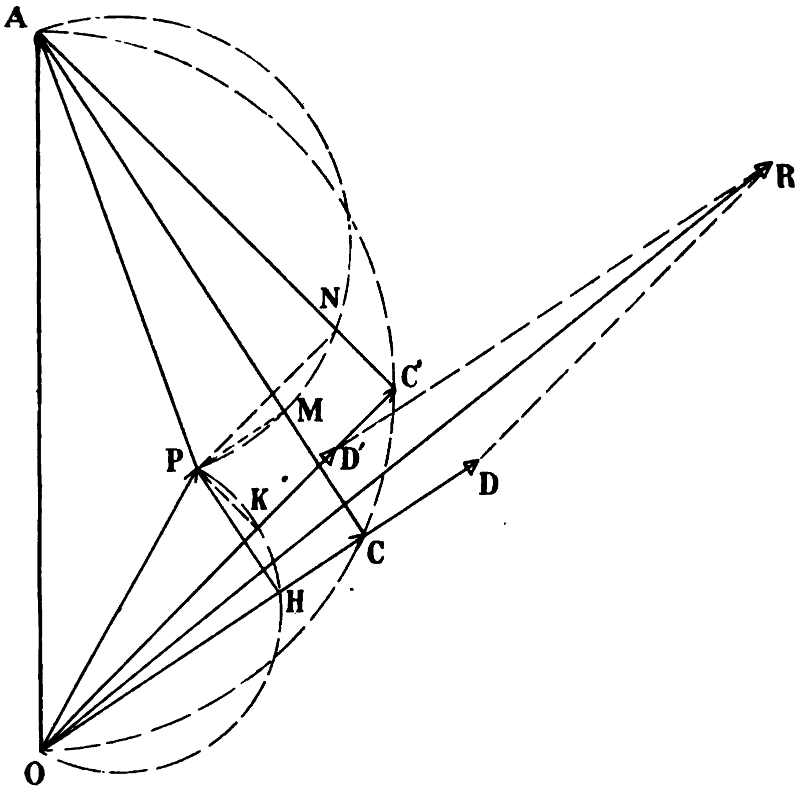

FIGURE 8.

Diagram the same as Fig. 7, except that the points P and Q are brought into coincidence, a necessary condition for zero current in the galvanometer of a Wheatstone's Bridge.

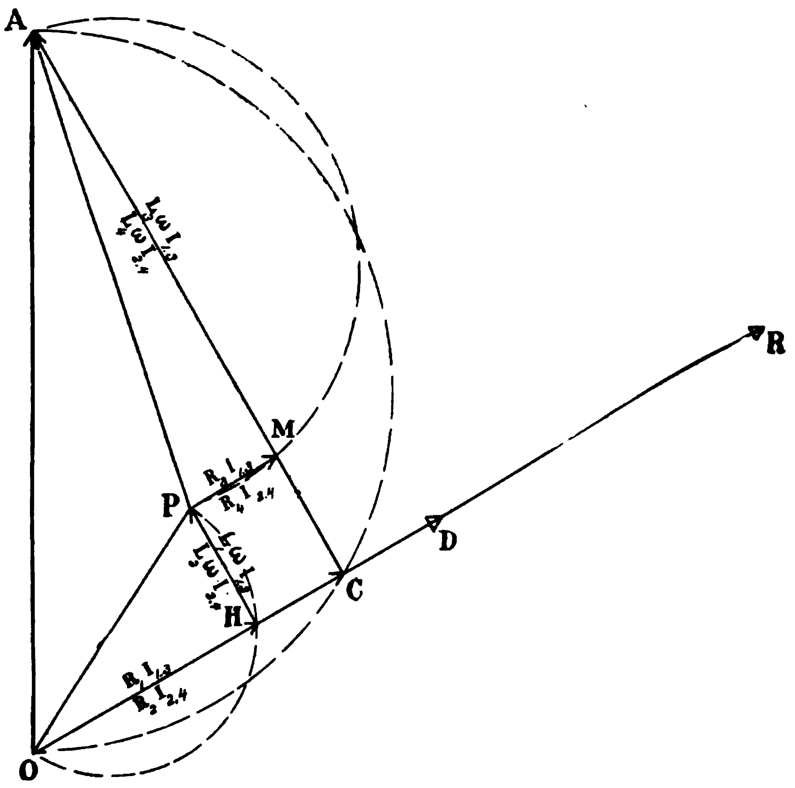

FIGURE 9.

Diagram the same as Fig. 8, except that the points M and N also H and K are brought into coincidence, a condition necessary for zero current in the galvanometer if $R_1 = R_2$ and $L_1 = L_2$.

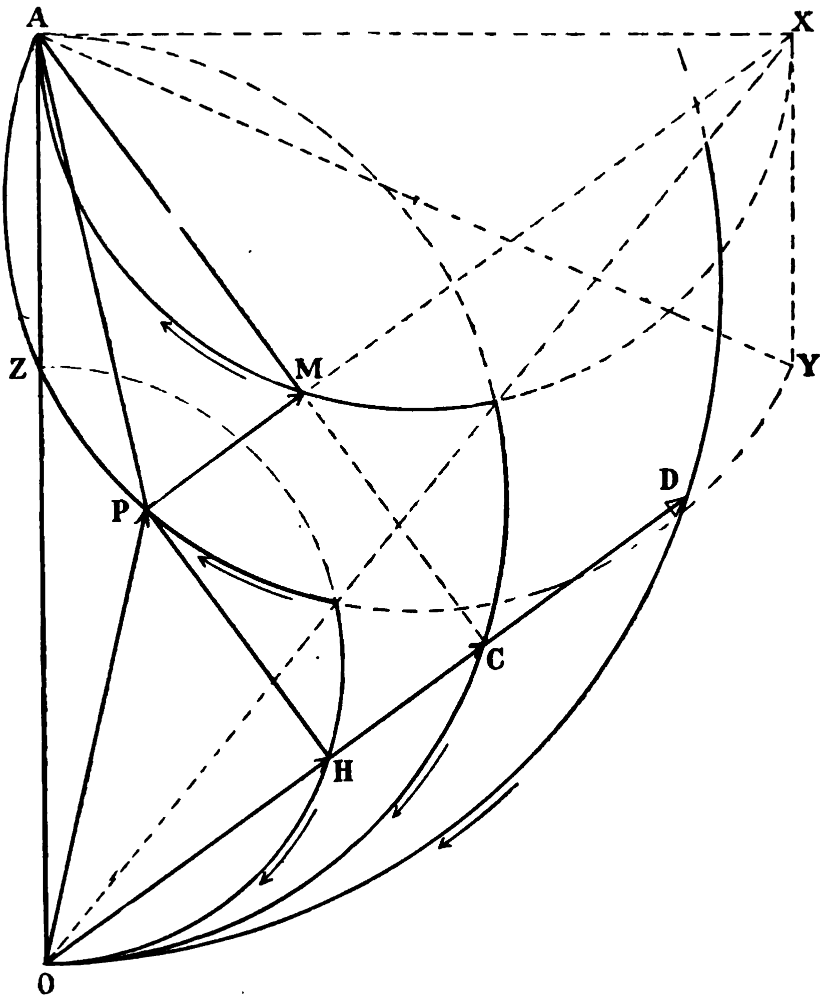

FIGURE 10.

Showing how the points of Fig. 9 move as the inductances L_1 and L_2 vary.

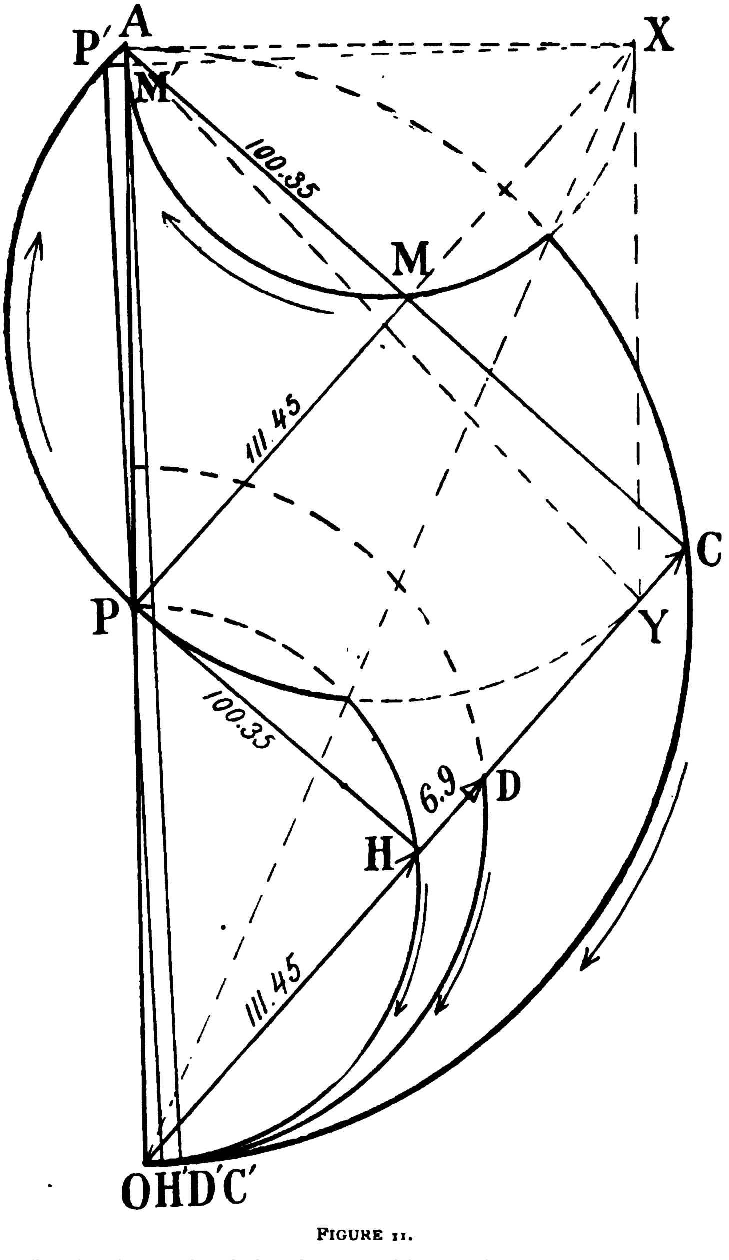

FIGURE 11.

Showing the actual variation of the quantities used from when the iron cores are all out until two of them are entirely in.

Scale: 1 cm. = 20 volts.

" 1 cm. = 1 ampere.

These spools were 44 cms. long, and 2.5 cms. in diameter to the windings. The hole through the center is 2.3 cms. in diameter. The wire is No. 22 single cotton insulated copper wire wound in 8 layers of 492 turns per layer making a total of 3,936 turns. The four iron cores were all made alike of soft iron wire, No. 16 insulated with single cotton, and cut into uniform lengths of 44 cms. The mass of each core was 407 grams. After the coils were made their resistances were measured by the Wheatstone's bridge to be,

Coil AC (1)	16.11 ohms.
Coil AD (2)	16.28 ohms.
Coil CB (3)	16.20 ohms.
Coil DB (4)	16.17 ohms.

The reactances and inductances were also measured for each coil, both when the iron cores are removed for minimum reactance, and when they are in the central position, for maximum reactance. These measurements were taken by the voltmeter and ammeter. Writing the equation for current in an alternating circuit, we have,

$$I = \frac{E}{J} = \frac{E}{\sqrt{R^2 + L^2\omega^2}} .$$

Solving the above for J and for $L\omega$ we may write,

$$J = \frac{E}{I} ,$$

$$L\omega = \sqrt{\frac{E^2}{I^2} - R^2} = \sqrt{J^2 - R^2} ,$$

where the quantities that occur in the right hand members are easily measured. For example the voltmeter reading at the terminals of coil AC (1) was 95.5 volts, while the ammeter in circuit read 4.40 amperes. Hence

$$J_1 = 95.5/4.40 = 21.6 \text{ ohms (impedance)},$$

$$L_1\omega = \sqrt{21.6^2 - 16.11^2} = 14.5 \text{ ohms (reactance)}.$$

and knowing the speed of the generator to be such as to make ω equal to 876, we find that

$$L_1 = .0166 \text{ henrys (inductance)}.$$

This was the value obtained when no iron core is inserted. When the iron core is inserted, the current falls off rapidly, so much so that the ammeter used before would no longer answer the purpose. In this case the current was determined by reading the potential difference at the terminals of a non-inductive resistance inserted in the circuit, the resistance being previously determined.

Incandescent lamps were used cold, their resistance having been so measured, as the non-inductive resistance. Its value was 213 ohms. The voltmeter read 18.75 volts at its terminals, giving a current,

$$I_1 = \frac{18.75}{213} = .089 \text{ amperes.}$$

The reading at the terminals of coil (1) was 82.5 volts. This gives the impedance

$$J_1 = \frac{E_1}{I_1} = \frac{82.5}{.089} = 926 \text{ ohms.}$$

It is seen how the insertion of the iron core has increased the impedance, mainly on account of the reactance of the circuit. In fact the resistance, although 16.11 ohms, is so small that it has no appreciable effect upon the impedance and so upon the current; for example, the reactance

$L_1\omega = \sqrt{J_1^2 - R_1^2} = \sqrt{926^2 - 16.11^2} = 925.85$, only .15 of an ohm less than the whole impedance above.

The value of ω obtained from the speed of the generator at the time was 853, hence

$$L_1 = 1.084 \text{ henrys (inductance).}$$

The values of the inductances of the four coils with and without the iron cores were found to be alike within the error of measurement. The value of the inductance of each coil is not far from 1.08 henrys with iron cores, and .017 without iron cores.

It is interesting to note that the inductance is increased about 64 fold by inserting the iron core.

In Fig. 11 is a diagram representing currents and E.M.Fs. as actually used. The impressed E.M.F. was obtained from the secondaries of five transformers connected in series in the laboratory, which gave about 300 volts at the terminals of the bridge. This is represented by the line *OA*. The resistances of the circuits *AC* and *CB* being 16.11 and 16.20 ohms respectively give a total of 32.31 ohms in one branch. The reactances of the same circuits are about 14.5 ohms each with no iron, and 926 ohms with iron. This makes the impedance of two circuits in series with no iron,

43.4 ohms,

with iron in both,

$$1852 \text{ ohms,}$$

with iron in one,

$$940.35 \text{ ohms.}$$

The current OD equal to I, is therefore, with no iron,

$$I = \frac{300}{43.4} = 6.9 \text{ amperes,}$$

with iron in both,

$$I = \frac{300}{1852} = .162 \text{ amperes,}$$

with iron in one,

$$I = \frac{300}{940.35} = .318 \text{ amperes.}$$

Fig. 11 represents the case when no iron is in either coil, and shows the variation of the points as two cores are inserted one into each coil, until they are entirely in. The angle AOC is laid off for no iron, equal to

$$\text{arc tan } \frac{\Sigma L\omega}{\Sigma R} = \frac{29}{32.31} = .9 \text{ approx.}$$

Hence $\theta = 42°$ approximately. The E.M.F. OC is therefore 222.9 volts, and as the resistances are approximately equal, the point H (the letters of all the Figures denoting corresponding points) bisects OC. As the reactances of all coils are approximately equal, the point M also bisects AC, and hence P lies at the middle point of OA. The current OD is 6.9 amperes, in each circuit, making a total of 13.8 amperes in the main line. Any change made by introducing the two iron cores, has the effect of moving the points upon the heavy portions of their respective circles in the directions of the arrows as the cores are introduced, until the point P arrives at P', when the cores are entirely in. The points H, C, M, and D move to H', C', M', and D' when the iron cores are inserted into one pair of coils.

CONCLUSION.

During the progress of the experiments described above, a number of possible variations which naturally suggested themselves were tried, the details of which need not be given at this time. The influence upon the error of setting by means of the galvanometer, produced by placing the two fixed coils of the bridge at station H so that they would have a mutual induction between them was tested, as well as the effect of arbitrarily inserting inductance in series with the iron telegraph line wire running between the stations. To secure a mutual induction between the fixed coils of the bridge, it was only necessary to place them side by side and then insert insulated iron wires bent around to form a continuous ring through both coils. This enabled the mutual induction to be increased gradually by adding wires, and the effect upon the galvanometer observed at each stage. By reversing the connections of one of the coils thus mutually related so that the magnetomotive forces of the two coils were opposed to each other, this case was easily tested. In general it may be said that these variations in the arrangement of the bridge gave results inferior to those outlined above. The effect upon the error of setting of decreasing the inductance of the fixed coils by wholly or partly removing the iron cores from them was noted, and as expected, produced a decreased sensibility.

Although much has been accomplished during the last ten years towards developing a range and position finder suited to the actual needs of sea-coast forts, yet the subject still seems far from settled, which is the more unfortunate since upon the range finder system adopted depends in a great measure the entire detail of fire direction and control.

Any discussion of the merits of horizontal base *versus* vertical base instruments is clearly uncalled for, but other things being equal, the desirability of having a base which may be a mile or more in length, operated from stations which may be effectively screened and protected from the enemy's fire, seems apparent.

One of the greatest arguments which has been urged against the horizontal base system, is the difficulty which two observers experience in turning their telescopes upon the same object from the two ends of the base. Mistakes are often made and much time is required to correct them by telegraph or telephone.

The above objection to the use of a horizontal base, does not seem necessarily inherent with the system, as a number of remedies may possibly be found. For instance, it is possible as has been suggested, that from comparatively rough observations for range and azimuth from the principal base-end, relocated by a simple attachment, that the approximate azimuth of the object selected can be sent at once to the other observer so that when he is directed to set his telescope at a certain azimuth, if the object is not found within the field of view of his telescope, it will at least be near enough in line to enable it to be readily identified.

From the very nature of the problems of sea-coast fire, a position finder should include some form of accurate map or plotting board by which the positions of the moving object can be located as well as its future positions predicted. After so much care has been devoted to accurately measuring the angles and producing parallelism at a distance, this should not be vitiated by a rough and poorly designed method of mechanical plotting, in other words, the error of the plotting board proper should at least not be greater than that caused by the error in producing parallelism. A form of board made of heavy ground glass or other suitable material, on which the plotting is indicated by the intersection of perfectly straight and unbending hair-lines, has been experimented upon in a crude way in the laboratory, and the results justify further trials. Such an arrangement would at once remove from the board the long cumbersome mechanical arms which are often a source of much error.

By referring to the table above, giving the error of setting for parallelism by means of the galvanometer from twenty different observations, it is seen that even with the very rough and home made apparatus which was used in these experiments, the results obtained are within the limits of the requirements for good range finding at present.

The mean error of 2.775 minutes of arc, is equivalent to but 1.39 yards at the distance of a mile, or 7.9 yards at the distance of 10,000 yards or 5.68 miles. The probable error of a single observation is but 2.67 minutes of arc, and the greatest error 8.75 minutes corresponds to about 25 yards in 10,000.

The theoretical discussion of a Wheatstone's bridge for an harmonic impressed electromotive force, has a scientific interest independent of its particular application to the range finder problem.

ON THE RIFLING OF CANNON.

(Continued from Volume VI, page 152.)

Since the appearance of the first part of this paper the writer has been reliably informed that unpublished experiments with a new form of colloidal powder (not yet put upon the market, but upon which great hopes are based), have proven conclusively that the rate of burning of this particular powder varies directly with the pressure to which it is subjected during the burning. The formulas heretofore given for velocity and pressure in the bore of a gun are based upon a velocity of burning, varying as the square root of the pressure—a law first adopted by Sarrau for ordinary charcoal powders, and which, as has been shown by the experiments of Vieille,* is not correct *merely as a law of burning;* though when this law is introduced into ballistic formulas it renders them wonderfully exact for both black and brown powders, due probably to its compensating for some other inexact hypothesis, for example, that of Piobert relative to the combustion of the grains by parallel layers, which Vieille has shown to be incorrect for ordinary charcoal powders at the high pressures that obtain in guns—though true for colloidal powders in all cases. As an example of the compensation of erroneous hypotheses Sebert and Hugoniot experimented in 1880, at the firing grounds of the Sévran-Livry powder works with a 10-cm. cannon loaded with a charge of black charcoal powder manufactured in 1878.† In their study of the action of this powder in the gun, guided by their experiments, they arrived at the conclusion that the velocity of combustion was proportional to the pressure. But, as already stated in the first part of this paper, the velocities determined by them at various positions of the projectile in the bore, have been very exactly reproduced by formulas based upon a rate of combustion proportional to the square root of the pressure.

The experiments of Vieille, already referred to, prove that for *collodial powders* the combustion is by parallel layers, and also that the rate of burning is proportional to a higher power of the pressure than obtains with charcoal powders. He found that the power of the pressure proportional to the velocity of combustion varies from $\frac{1}{4}$ to $\frac{2}{3}$ in passing from compact brown-powder compositions to plain gun-cotton powder. He also found that the law connecting the velocity of combustion of explosives with the pressure cannot be stated in general terms, and that it is a characteristic of each particular powder quite as much as the *force* and the time of combustion in free air.* The claim then made by the inventors of the new collodial powder to a rate of burning exceeding any deduced by Vieille does not necessarily conflict with his experiments, which were confessedly far from exhaustive, and were moreover made with a small quantity of powder exploded in an eprouvette of a few cubic inches capacity, which may possibly be a very different matter from the burning of a much larger quantity in the bore of a gun. Certainly the amount of heat lost by conduction must differ greatly in the two cases.

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* Memorial des poudres et Salpêtres. Tome VI, 1893.

† Memorial de l'Artillerie de la Marine, 1882.

It may be considered certain that some form of colloidal powder will be adopted in the near future for all our guns; and the tendency seems to be to diminish the rate of burning by increasing the density of the grains, and by other means, so that the velocity of combustion may not be more than an inch or two per second, even under the high pressures that obtain in cannon. By this means the undeniable advantages resulting from a larger charge, which is not all burned in the gun, is secured, with a less maximum pressure and with increased muzzle velocity. It will therefore be desirable before proceeding further with the subject of rifling to deduce if possible, working formulae for velocity and pressure based upon this new law of combustion. The convenience of such formulas in discussing rifling and kindred subjects is apparent.

It will be assumed that the pressure to which the grains are subjected while burning is equal, during the same intervals of time, to the pressure, per unit of surface, upon the breech block; and that this pressure is the same as that upon the base of the projectile *increased in weight by a fraction of the charge*. The pressure, then, will be measured by the acceleration of this hypothetical projectile. This assumption is only approximately correct and is on a par with several other assumptions that will be made during this discussion in order to establish the desired equations. All ballistic formulae (whether exterior or interior) are more or less inexact and empirical; and their practical value must be established by experiment, as indeed is the case with all physical equations.

Let l_0 be one-half the mean least dimension of one of the equal grains of which a modern charge of powder is composed, τ the time of combustion of the entire grain under the normal atmospheric pressure p_0, and l the length of grain burned in time t under the variable pressure p. Then it can be shown that, for most regular geometric forms of grain employed for the charges of heavy guns, and which burn in parallel layers, the weight of powder burned at any instant in the gun is a definite function of the corresponding length of grain burned. In fact we have the relation

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* Construction Note, No. 72.

$$\frac{y}{\bar{\omega}}=a\frac{l}{l_0}\left\{1-\lambda\frac{l}{l_0}+\mu\left(\frac{l}{l_0}\right)^2\right\}$$

in which y is the weight of powder burned at any instant, $\bar{\omega}$ the entire weight of charge, and a, λ, μ factors depending upon the form of grain. For all the various forms of powder grains used in heavy guns, μ is practically zero, and will be so taken in what follows. We therefore have, for the charges of heavy guns, the relation

$$\frac{y}{\bar{\omega}}=a\frac{l}{l_0}\left\{1-\lambda\frac{l}{l_0}\right\} \tag{1}$$

In this equation l/l_0 is the fraction of grain (linear) burned at any instant, and $y/\bar{\omega}$ the corresponding fraction of weight of charge burned. When $l=l_0$, that is when all the grains are burned, we must have also $y=\bar{\omega}$; and equation (1) becomes

$$1=a(1-\lambda), \tag{2}$$

a formula giving the relation existing between a and λ, and which is satisfied either exactly or to a near degree of approximation, for all forms of grain now in use. For example if the grain is a cylinder pierced with an axial cylindrical hole the values of a and λ depend upon the ratio of the diametral thickness of the grain to its length. Representing this ratio by $1/m$ we have

$$a=1+\frac{1}{m}, \text{ and } \lambda=\frac{1}{1+m}.$$

Our pierced prismatic grains assimilate to this form, and since in these $m=2$, we have $a=\frac{3}{2}$ and $\lambda=\frac{1}{3}$. For the long cylindrical or thread like grains (of which Cordite is a type), $a=2$, and $\lambda=\frac{1}{2}$, very approximately. Another form of grain which is coming into general use is a cylinder pierced with several small holes symetrically arranged about its axis. For this form a and λ differ but little from the cordite type of grain. These three classes embrace nearly all the forms of grain which have found favor with artillerists, and all satisfy equation (2) very closely—

though the first form (pierced cylinder) is the only one of them that satisfies it exactly.

We will now deduce an expression for the ratio l/l_0 in terms of the corresponding travel of the projectile. We have when the rate of burning varies as the pressure,

$$\frac{dl}{dt}=\frac{l_0 p}{\tau p_0} \tag{3}$$

and

$$\frac{p}{p_0}=\frac{w'}{g\,\omega\,p_0}\cdot\frac{d^2u}{dt^2} \tag{4}$$

In these equations w' is the weight of the hypothetical projectile, ω the area of its base, u the travel of projectile from the origin in time t, g the acceleration of gravity, and p the pressure per unit of surface upon the base of the projectile. Substituting from (4) in (3) gives

$$\frac{dl}{dt}=\frac{l_0 w'}{\tau g\,\omega\,p_0}\cdot\frac{d^2u}{dt^2} \tag{5}$$

It will be convenient to eliminate the time from this equation, making the travel of the projectile u the equicrescent variable. We have for this purpose

$$\frac{d^2u}{dt^2}=\frac{v\,dv}{du},$$

and

$$\frac{dl}{dt}=\frac{dl}{du}\cdot\frac{du}{dt}=v\frac{dl}{du}.$$

Making these substitutions in (5) and dividing by v there results

$$\frac{dl}{du}=\frac{l_0 w'}{\tau g\,\omega\,p_0}\cdot\frac{dv}{du};$$

whence, integrating between the limits zero and u,

$$l=\frac{l_0 w'}{\tau g\,\omega\,p_0}v. \tag{6}$$

From this equation it follows that *when the rate of combustion of a grain of powder varies directly as the pressure to which it is subjected in the gun, the length of grain burned at any instant is proportional to the corresponding velocity of the projectile.* When the grain is all burned we have $l=l_0$, and therefore if we designate the corresponding value of v by v_0, we shall have

$$v_0=\frac{\tau g\,\omega\,p_0}{w'}, \tag{7}$$

and therefore

$$\frac{l}{l_0}=\frac{v}{v_0} \tag{8}$$

Substituting from (8) in (1) gives

$$\frac{y}{\bar{\omega}}=a\frac{v}{v_0}\left\{1-\lambda\frac{v}{v_0}\right\}, \tag{9}$$

an equation which gives the weight of powder burned at any instant in the gun, in terms of the corresponding velocity of the projectile.

The ratio κ of the specific heats of the gases formed by the combustion of powder, whether black or smokeless, has never been definitely determined; and writers on interior ballistics have employed various values for this ratio ranging from 1.406, its value for perfect gases at ordinary temperatures, to 1.2 deduced by Wuich for an adiabatic expansion,*—or even less. We will leave this ratio undetermined at present and write

$$\kappa=1+\frac{1}{n}.$$

With this expression for the ratio of specific heats, the well known equation for the square of the velocity of a projectile in the bore when a weight of powder y has been burned becomes

$$v^2=\frac{2nfg}{w'}\left\{1-\frac{1}{(1+x)^{\frac{1}{n}}}\right\}y. \tag{10}$$

In this equation, which is deduced upon the assumption of an adiabatic expansion of the gases as they are formed by the combustion of the grains, x is the number of volumes of expansion of the gases, and f a factor to be determined by experiment, though theoretically representing the so called *force of the powder*. Making, for simplicity,

$$X^2=1-\frac{1}{(1+x)^{\frac{1}{n}}},$$

and

$$A^2=2nfg,$$

equation (10) becomes

$$v^2=A^2\frac{y}{w'}X^2. \tag{11}$$

Substituting the value of y in terms of v from (9) in (11) and making

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* *Mittheilungen über Gegenstände des Artillerie und Genie-Wesens*, No. 1, 1891. Translated by Lieutenant Willcox and published in the *Journal U.S. Artillery*, Vol. 2, p. 408.

$$M = \frac{r_0}{\lambda} = \frac{\tau g \omega p_0}{\lambda w'},$$

$$N = \frac{1}{a\lambda}\left(\frac{v_0}{A}\right)^2 \frac{w'}{\omega},$$

$$X_1 = \frac{1}{X^2},$$

we have finally

$$v = \frac{M}{1 + N X_1}. \tag{12}$$

In deducing equations (10) and (12) it has been assumed that the entire work stored up in the gases produced by the combustion of the charge is expended in giving motion of translation to the projectile and charge, or rather would be if the bore were indefinitely prolonged. This does not change the *law of expansion*, but it does rob the factor f of much of its physical significance, making it largely an empirical factor whose value in any case must be determined by experiment.

With the assumptions already made an expression for p, the pressure per unit of surface upon the base of the hypothetical projectile, can easily be determined from (12) by differentiation. We have the general equation of energy

$$p = \frac{w'}{g\omega} \cdot \frac{v\,dv}{du};$$

or, making

$$x = \frac{u}{z_0},$$

in which z_0 is a constant to be determined later,

$$p = \frac{w'}{g \omega z_0} \cdot \frac{v\,dv}{dx}. \tag{13}$$

Differentiating (12) with reference to x we have

$$\frac{v\,dv}{dx} = -\frac{M^2 N \frac{dX_1}{dx}}{(1 + N X_1)^3};$$

whence, substituting in (13), and making

$$M_1 = \frac{M^2 N}{g\omega} \cdot \frac{w'}{z_0},$$

and

$$X_2 = -\frac{dX_1}{dx},$$

we have

$$p = \frac{M_1 X_2}{(1 + N X_1)^3}; \tag{14}$$

or, retaining v,

$$p = \frac{N w' v^2 X_2}{g \omega z_0 (1 + N X_1)}. \tag{15}$$

The quantities X, X_1 and X_2 are functions of x, that is, of the number of volumes of expansion of the gases in the bore; and are therefore abstract numbers which can be tabulated for use with any gun and charge. They can be simplified for computation by employing an auxiliary angle φ defined by the relation

$$\sec \varphi = (1 + x)^{\frac{1}{2n}}.$$

In terms of this angle we easily find

$$X = \sin \varphi,$$

$$X_1 = \operatorname{cosec}^2 \varphi,$$

$$X_2 = \frac{\operatorname{cosec}^4 \varphi}{n(1 + x)^{\kappa}}.$$

When we are certain that the powder has not all been burned before the projectile leaves the gun the best way to determine the constants M and N is to measure the velocity of the projectile at two well chosen points within the bore, when this is practicable, which furnishes the two equations

$$v_1 = \frac{M}{1 + N X_{11}}, \text{ and } v_2 = \frac{M}{1 + N X_{12}},$$

by means of which we find

$$N = \frac{v_2 - v_1}{v_1 X_{11} - v_2 X_{12}}, \tag{16}$$

and

$$M = v_1 (1 + N X_{11}) = v_2 (1 + N X_{12}). \tag{17}$$

Though, as has been stated, the factor f cannot be considered as representing even approximately the force of the powder, still it may be of some importance in giving the comparative values of the force of the powder for different powders. It may be computed from the experimental values of M and N by the equation

$$f = \frac{M^2}{2 n g N} \cdot \frac{\lambda w'}{a \tilde{\omega}}. \tag{18}$$

We may also determine τ from the equation

$$\tau = \frac{M \lambda w'}{g \omega p_0} = \frac{w' v_0}{g \omega p_0}. \tag{19}$$

When the velocities v_1 and v_2 cannot be measured, the next best way to determine M and N (a method that can always be employed when we are sure that the powder has not all been burned in the gun), is to fire two projectiles differing greatly in weight, from the same gun and with similar charges, and measuring the muzzle velocity of each shot. Let

$$M' = Mw' = \frac{g \omega p_0 \tau}{\lambda};$$

and

$$N' = Nw'\bar{\omega} = \frac{g(\omega p_0 \tau)^2}{2 n a \lambda f}.$$

Then the expression for the velocity in terms of these new constants becomes

$$v = \frac{M'\bar{\omega}}{w'\bar{\omega} + N' X_1}. \tag{20}$$

If V_1 and V_2 are the two measured muzzle velocities, and w'_1 and w'_2 the corresponding weights of projectiles, increased by a fraction of the charge, we shall find from (20)

$$N' = \frac{\bar{\omega}(V_1 w'_1 - V_2 w'_2)}{(V_2 - V_1) X_1}, \tag{21}$$

in which, of course, X_1 refers to the muzzle. It will be observed that the new constants M' and N' are independent of the elements of loading. The method frequently adopted for deducing the constants f and τ from data obtained by firing two guns of different calibers, lengths of travel of projectile, etc., cannot be recommended. The constants thus obtained do not pertain to either gun and are misleading. The method of deducing M and N when the powder is all burned in the gun will be given further on.

It is probably true in many cases that the powder is all converted into gas before the projectile leaves the bore, and that for a certain distance along the chase the projectile is acted upon by the (approximately) adiabatic expansion of a *constant* mass of gas, which, for smokeless powders, is equal to the mass of the charge. For this part of the bore, then, we have from (11)

$$v = A\left(\frac{\bar{\omega}}{w'}\right)^{\frac{1}{2}} X, \tag{22}$$

in which

$$A = \sqrt{2 n g f},$$

and

$$X = \sin \varphi,$$

where φ is determined by the relation

$$\sec\varphi = (1+x)^{\frac{1}{2n}}.$$

For the pressure for this part of the bore, we have as before

$$p = \frac{w'}{g\,\omega\,z_0} \cdot \frac{v\,dv}{dx}.$$

But from (22), by a simple reduction,

$$\frac{v\,dv}{dx} = \frac{g\,f\,\tilde{\omega}}{w'(1+x)^\kappa};$$

whence, finally,

$$p = \frac{f\,\tilde{\omega}}{\omega\,z_0(1+x)^\kappa} = \frac{A^2\,\tilde{\omega}}{2n\,g\,\omega\,z_0(1+x)^\kappa}. \tag{23}$$

To determine the value of the constant A we have from (22), if V is a measured muzzle velocity,

$$A = \left(\frac{w'}{\tilde{\omega}}\right)^{\frac{1}{2}} V \operatorname{cosec}\varphi, \tag{24}$$

where φ refers to the muzzle. Having determined the value of A we may then compute the value of f by the equation

$$f = \frac{A^2}{2ng} \tag{25}$$

for comparison with the value given by (18).

It may be remarked that the foregoing formulas are independent of any particular units of weight and length, and can be used without change either for English or French units.

To test the practical value of the preceding formulas for colloidal powders, and to determine, if possible, a proper value for κ to be used with them, we will take for comparison the experiments made with great care by Lieutenant Wheeler of the Ordnance Department, at Sandy Hook, December 14 and 15, 1894, with an 8-inch B. L. rifle mounted on a free-recoil carriage.[*] The velocity of recoil was determined at very short intervals of time by a Sebert velocimeter, and from these velocities the corresponding pressures on the breech, and the velocities of the projectile at various points within the bore were, among other things, deduced in the usual manner.[†] Six shots were fired in all, the first and fourth with charges of Dupont's brown prismatic powder for 8-inch rifles, and the others with Maxim-Schüpphaus smokeless powder made in the form of cylindrical grains one inch long and seven-sixteenths of an inch in diameter, pierced by seven small holes each one-twentieth of an inch in diameter. The specific gravity of this latter powder was 1.5884.

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[*] Lieutenant Wheeler's report on his experiments is published as "Notes on the Construction of Ordnance", No. 69. Washington, January 10, 1894.

[†] For a very complete exposition of the methods employed in such deductions see translation of Sebert and Hugoniot's paper in Construction Note No. 62. Also some very valuable and original papers by Lieutenant Mattei of the Italian Artillery, contributed to the *Rivista di Artiglieria e Genio* for 1894, 1895 and 1896.

We will take the second shot of the series for a first comparison and test of our formulas. This shot was fired with a charge of 50 pounds of the smokeless powder just described and 10 ounces of rifle powder as an igniter. As it is impossible to isolate the action of each kind of powder we will consider the charge in its entirety, and take $\bar{\omega} = 50.625$ pounds. The projectile weighed 300 pounds, and this, following the most approved practice,[*] we will increase by one-half the weight of the charge, for the weight of the hypothetical projectile. We therefore have $w' = 325.3125$ pounds. For computing the value of x (the number of volumes of expansion of the gases for any travel u of the projectile) we will take for z_0, in the equation

$$x = \frac{u}{z_0},$$

the reduced length of the initial air space computed by the well known formula

$$z_0 \omega = C - h \frac{\bar{\omega}}{\delta},$$

in which C is the volume of the powder chamber, h the volume of unit weight of water, and δ the specific gravity of the powder. If C is taken in litres and $\bar{\omega}$ in kilograms the value of h is unity. But if, as is customary with us, C is given in cubic inches and $\bar{\omega}$ in pounds, then $h = 27.6807$ cubic inches. For the 8-inch B. L. rifle in question, $C = 3597$ cubic inches. The above equation gives the correct value of z_0 (to be used in computing x), for gunpowder, as was shown by Noble and Abel; and the researches of Sarrau upon the co-volume of a gas[†] prove that it is approximately correct for all kinds of smokeless powders.

It is not known what the rate of burning of the Maxim-Schüpphaus powder is, though it is probably less than that claimed for the new powder. But if the charge be all burned while the projectile is still in the bore, as seems to have been the case with the fifty-pound charge in the 8-inch B.L.R., then for the remainder of its travel the projectile is accelerated by the expansion of the entire mass of gas into which the charge has been converted, and all consideration of the manner of burning is eliminated. For this part of the chase equation (22) should give the velocity of the projectile with considerable accuracy when the constant A and the ratio of the specific heats κ are known. The former can be computed from a given muzzle velocity by equation (24), provided the value of κ, which enters into cosec φ, is also known. Assuming the correctness of the experimental velocities we may determine by trial, without too excessive labor, a value for κ which in equation (22) gives velocities agreeing most nearly with these. Moreover the position of the projectile when the powder is all consumed should be indicated with some precision by a marked divergence at this point between the computed and experimental velocities. Table I gives the results of such calculations, the muzzle velocity being 2020 f.s.:—

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[*] See Lieutenant Mattei in *Rivista d'Artiglieria e Genio*, 1896, Vol. 3.

[†] *Mémorial des Poudres et Salpêtres*, for 1894.

TABLE I.

Travel of projectile. u (inches.)	Experimental velocity. (f.s.)	Computed velocity. $\kappa = 1\frac{1}{3}$.	Computed velocity. $\kappa = 1\frac{1}{10}$.	Computed velocity. $\kappa = 1\frac{1}{6}$.	Ex.—Comp. $\kappa = 1\frac{1}{6}$.
1.607	184.8	312.3	287.0	294.1	—109.3
4.937	348.7	536.9	494.9	506.9	—158.2
9.896	540.4	739.5	685.0	700.6	—160.2
17.009	802.0	935.2	871.6	889.8	— 87.8
27.017	1080.9	1126.1	1057.4	1077.2	+ 3.7
43.244	1293.6	1336.1	1267.6	1287.4	+ 6.2
61.114	1450.5	1495.3	1431.9	1450.4	+ 0.1
78.759	1572.5	1611.7	1555.5	1572.0	+ 0.5
98.592	1680.6	1713.1	1665.8	1679.7	+ 0.9
118.086	1767.8	1792.6	1754.4	1765.7	+ 2.1
140.326	1848.0	1866.5	1838.6	1846.9	+ 1.1
162.159	1917.7	1926.6	1908.6	1914.0	+ 3.7
186.749	1977.0	1983.6	1976.1	1978.4	— 1.4
204.890	2020.0	2020.0	2020.0	2020.0	0.0
Infinite.		3166.7	5303.6	4213.1	

The velocities in the fifth column were computed by the equations

$$v = 4213.0 \sin \varphi, \tag{26}$$

$$\sec \varphi = (1 + x)^{\frac{1}{12}},$$

and

$$x = \frac{u}{54.0086},$$

in which u is taken in inches.

These velocities agree very closely with those determined by experiment, from $u = 27.017$ inches to the muzzle, and afford a strong presumption that the ratio of the specific heats of the gases produced by the combustion of Maxim-Schüpphaus powder in the bore of a gun is in the neighborhood of $1\frac{1}{6}$, at least for the purposes of calculation. Shot number 3 makes this ratio a little greater than $1\frac{1}{6}$ and shots numbers 5 and 6 a little less. This ratio agrees extremely well with that obtained by Wuich, already referred to, and also with the ratio deduced by Krupp from velocity measurements.

The sudden and great increase in the computed over the experimental velocities from $u = 27.017$ inches to the origin of motion is due to the fact that in this part of the bore the powder is still burning, while equation (26) assumes that it had all been converted into gas before the projectile moved from its seat. This is also illustrated by the expression for the pressure upon the base of the hypothetical projectile, deduced from equation (23), which is, in pounds per square inch,

$$p = \frac{66150}{(1+x)^{\frac{7}{6}}} \tag{27}$$

The pressure given by this formula may also be assumed to be the pressure on the breech-block. Making $x = o$ gives $p = 66150$ pounds per square inch, which is the initial pressure on the breech-block upon the hypothesis that all the powder had been converted into gas before the projectile started. If we go to the other limit and suppose the bore to be indefinitely prolonged, we shall have at the limit, $p = o$, and $v = 4213.1$ f.s. Equations (26) and (27) therefore not only give velocities and pressures in the bore of the gun which are remarkably in accord with experiment but they also give probable, or, at any rate, consistent results at both limits, which is seldom true of empirical formulas.

If we construct a pressure-space curve from (27) by taking the spaces for abscissas and the pressures for ordinates it will be found to be convex toward the axis of spaces. This is also evident analytically since the second differential coefficient of p with reference to x is positive for all positive values of x.

An examination of Table I would seem to indicate that the powder was all burned at or near where $u = 27.017$ inches. But it is pretty certain that two of the velocities given in the table as "experimental", namely, when $u = 27''.017$ and $u = 43''.244$, are both too great and that the agreement here is only apparent.

The "experimental" velocities are deduced from the pressures and in the two cases above cited the pressures and velocities do not correspond at all well. That is to say, as an example, it would require a mean pressure of 58,000 pounds per square inch upon the base of the *real* projectile acting through 10.008 inches, to increase its velocity from 802.0 f.s. to 1080.9 f.s.—which pressure is much too great, and these velocities are therefore too great. The experimental pressures and velocities correspond quite well from the muzzle to $u = 61.114$, but not beyond that point. We will therefore take for the point where the powder is all burned

$$u_0 = 61.114 \text{ inches}$$
$$v_0 = 1450.5 \text{ f.s.}$$
$$\log \sin \varphi_0 = 9.5368787$$

From the origin of motion to u_0 equation (12) holds, namely,

$$v = \frac{M}{1 + NX_1},$$

which must be satisfied at the point where the powder is all consumed. We therefore have, since $M = v_0/\lambda$,

$$v_0 = \frac{v_0/\lambda}{1 + NX_1},$$

and therefore

$$N = \frac{1 - \lambda}{\lambda X_1} = \frac{1 - \lambda}{\lambda} \sin^2 \varphi_0.$$

It is impossible to deduce analytically the precise value of λ for the Maxim-Schüpphaus grains; and we will therefore determine M and N from an experimental velocity and the corresponding pressure on the breech-block. Solving equation (15) for N and making

$$b = \frac{w'}{g \omega z_0},$$

we have

$$N = \frac{1}{\dfrac{b v^2 X_2}{p} - X_1} \tag{28}$$

and

$$M = (1 + NX_1)v \tag{29}$$

If the experimental velocities and pressures were exact it would be immaterial which we selected for the computation of M and N since they would all give practically the same values. But it is easy to see by comparing the results of the second and third shots (which were fired under identical conditions), that the first experimental pressure (see Table II), is much too great, and the third somewhat too small; and that the first two experimental velocities are too great.

We will therefore take the following data: $u = 61.114$ inches, $v = 1450.5$ f.s., and $p = 27500$ pounds per square inch. With these data and the gun constants, are derived; $\log(1+x) = 0.32870$, $\log X_1 = 0.92624$, $\log X_2 = 0.69085$ and $\log b = 8.65043 - 10$.

Substituting in equations (28) and (29) we obtain $\log N = 9.07834 - 10$, $\log M = 3.46484$, and $\log M_1 = 4.65846$. Whence finally,

$$v = \frac{[3.46484]}{1 + [9.07834 - 10]X_1} \tag{30}$$

and

$$p = \frac{[4.65846]X_2}{\left\{1 + [9.07834 - 10]X_1\right\}^2} \tag{31}$$

The following table (Table II) gives all the experimental pressures and velocities for the second shot; and also, for comparison, those computed by equations (26), (27), (30), and (31). The last column gives the weights of powder burned for the travel of projectile found in the first column. They were computed by the following formula deduced from equation (9):

$$y = 1.9895\, \bar{\omega} \left\{ \frac{v}{v_0} - 0.49736 \left(\frac{v}{v_0}\right)^2 \right\}$$

About three-fourths of the powder was burned when the pressure had attained a maximum.

The agreement between the experimental velocities and those computed by equation (26) for the portion of the bore between $u = 61.114$ inches and the muzzle, that is for seven-tenths of the entire travel of the projectile, is most remarkable, and is much closer than is given either by the application of Sarrau's formulas to this shot or by the exponential formula deduced by Lieutenant Wheeler from a "mean of many values". From the origin of motion to $u = 61.114$ inches the agreement is not so close, as was to be expected. This section of the bore includes the point of maximum acceleration of the gun and projectile, and is therefore just where maximum errors in measuring the velocity of recoil should be looked for; and, as Lieutenant Wheeler remarks, "On account of the great difference in weight between the gun and projectile it can be readily understood that an error in the

TABLE II.

Travel of projectile in inches. (x)	Pressure on breech-block determined by		Difference.	Velocities determined by		Difference.	Weight of powder burned. lbs. (y)
	Experiment.	Equations (27) and (31).		Experiment.	Equations (26) and (30).		
1.607	30600	18467	+12133	184.8	114.1	+70.7	7.610
4.937	41000	41010	— 10	348.7	314.4	+34.3	19.479
9.896	49600	53843	— 4243	540.4	547.0	— 6.6	30.859
17.009	55050	55395	— 345	802.0	791.4	+10.6	40.041
27.017	48250	48718	— 468	1080.9	1029.7	+51.2	46.256
43.244	36000	36858	— 858	1296.3	1277.6	+18.7	49.851
61.114	27500	27500	000	1450.5	1450.5	0.0	50.625
78.759	22000	23158	— 1158	1572.5	1572.0	+ 0.5	
98.592	18800	19686	— 886	1680.6	1679.7	+ 0.9	
118.086	16400	17110	— 710	1767.8	1765.7	+ 2.1	
140.326	14650	14848	— 198	1848.0	1846.9	+ 1.1	
162.159	13150	13114	+ 36	1917.7	1914.0	+ 3.7	
186.749	11850	11565	+ 285	1977.0	1978.4	— 1.4	
204.890	muzzle	10625	—	2020.0	2020.0	0.0	
211.595	10750	10313	+ 437	2036.3	2034.4	+ 1.9	

velocity of recoil of the gun would be multiplied many times in determining the velocity of the projectile". As has already been stated the experimental velocities and pressures in this section do not correspond in value as well as those nearer the muzzle, though there can be no doubt as to their general mean correctness.

If the velocity of the projectile could be *accurately* measured at short intervals in that part of the bore where the powder is still burning, and especially between the origin and the point of inflection of the pressure-space curve, and this with various charges and weights of projectile, it would then be possible to take account of the various energies which were omitted in deducing our equations, and to derive from their discussion much valuable information. But at present there seems to be no practicable method known to artillerists for measuring these velocities accurately. The magnificent "Polarizing Photo-Chronograph", at the Artillery School, the invention of Professor Crehore of Dartmouth College and Lieutenant Squier, Instructor of Electricity, is delicate enough to measure accurately much greater accelerations than those pertaining to a projectile at the point of maximum pressure. But up to the present time no apparatus has been devised for connecting the moving projectile with the chronograph (without destroying the gun), which is able to withstand the tremendous shock of the explosion. It is hoped however that this difficulty will soon be overcome and that we shall then know what takes place in the bore of a gun as accurately as we can know anything that we cannot take cognizance of by the senses.

By differentiating equation (14) it will be found that the pressure is a maximum when

$$\sin^2\varphi = \tfrac{1}{5}\left\{ \sqrt{(4N+1)^2+5N} - (4N+1) \right\} \tag{32}$$

This equation gives the travel of the projectile when the pressure is a maximum, and when N has been determined by the method already given.

Substituting in this equation the value of N already found, namely

$$\log N = 9.07834 - 10,$$

it will be found that at the point of maximum pressure

$$\log \sin \varphi = 9.29013,$$

$$\log(1+x) = 0.10106,$$

and

$$x = 0.26201.$$

Therefore

$$u = 0.26201 \times 54.0086 = 14.15 \text{ inches}$$

which was the travel of the projectile when the pressure was a maximum. Substituting the values of $\sin\varphi$ and $1+x$ above given in equations (30) and (31) we find that at the point of maximum pressure

$$v = 703.0 \text{ f.s.}$$

$$p = 56008 \text{ lbs. per in}^2.$$

The maximum pressure on the breech-block as shown by experiment was 55650 pounds, which differs by about two-thirds of one per cent. from that computed by our formula.

Solving equation (32) for N we have

$$N = \frac{2+5X^2}{X_1-8} \tag{33}$$

If both the travel of projectile and its velocity could be accurately determined at the point of maximum pressure,—as they could be if we had the means for correctly measuring the velocities at several points in this neighborhood,—then equation (33) would afford the most accurate method for computing N, and thus locating the point where the powder is all consumed.

The mean maximum pressure as registered by two crusher gauges placed in the face of the breech-block was 32400 lbs. per in^2—only 58 per cent. of the pressure legitimately deduced from the motion of the gun recoiling freely. This is an enormous discrepancy and should, if possible, be explained. Lieutenant Wheeler in his paper notices this discordance and not being able to detect any error either in his experiments or his deductions therefrom, enters upon a lengthy and valuable discussion of the reliability of crusher gauges as at present employed, and comes to the conclusion that "Our crusher gauges used in guns of large caliber register incorrect pressures, partly from the manner in which the tarage tables are formed, the loads being allowed to act for too long a time, and partly from the manner in which the pressure in a gun is applied, the pressures being increased to the maximum so rapidly that no method of comparison in a static machine has yet been devised."

Lieutenant Dunn of the Ordnance Department, U. S. Army, has recently published the results of a study on the relation between the successive compressions of copper cylinders and the time occupied in producing them, by means of an extremely ingenious and delicate apparatus of his own invention which he calls a "photo-retardograph."* We can only give some of Lieutenant Dunn's conclusions which bear upon the subject under discussion. He says "This investigation indicates that powder pressures, determined by crusher gauges with static tarage, are too low, and that the probable errors from this source, when the time consumed by powder pressures in reaching a maximum is not less than 0.003 second, are between 4000 and 5000 pounds per square inch."

"That under ordinary service conditions (since the time required by powder pressures to reach a maximum is less than 0.003 second, or about 0.001 second), *the probable errors of crusher gauge will be greater than 5000 pounds per square inch.* The quicker the powder the greater the excess of actual over indicated pressures; and, for this reason, the error of crusher gauge is greater for small arms than for cannon."

Lieutenant Dunn also shows how his apparatus can be made to measure accelerations as well as retardations; and, how as thus modified, it can be used to measure the accelerations of a gun during free recoil after the manner of a Sebert velocimeter, but much more accurately, since by his method the acceleration curve would be automatically and accurately produced on a magnified scale.

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* For a description of the apparatus and of the experiments made with it see Lieutenant Dunn's paper published as Construction Note, No. 71. Washington, April 11, 1896. This paper will also be found in the present number of the *Journal.*

Lieutenant Dunn probably had in mind the 10-centimeter gun employed by Sebert and Hugoniot in making their experiments when he states that the time required for powder pressure to reach a maximum is about 0.001 second. For the 8-inch rifle under discussion this time is about 0.0045 second, and therefore the error of crusher gauge deduced by him cannot even approximately account for the enormous difference of maximum pressure found by Lieutenant Wheeler between the indications of the crusher gauge and the legitimate deductions from his experiments. As we have already stated, these matters could be definitely settled if we had the means of measuring accurately the velocity of the projectile at several points in the neighborhood of the position of maximum pressure. Of course if means can be devised to measure the *pressures* directly and accurately in this same neighborhood so much the better. It is simply a question of which is the easier to do. But it is manifestly of the greatest importance to know what the maximum pressure in our guns actually is—whether it is 32000 pounds per square inch or nearly double that—whether there is a liberal factor of safety in our heavy guns or none at all.

For the computation of τ and f we have the equations

$$\tau = \frac{v_0 w'}{g \omega p_0},$$

and

$$f = \frac{v_0^2 w'}{12 g N \bar{\omega}};$$

or, from a muzzle velocity, when the powder is all burned in the gun,

$$f = \frac{V^2 w'}{12 g \bar{\omega} \sin^2 \varphi}$$

The data to be used in these formulas are the following: $w' = 315.3125$ lbs., $\bar{\omega} = 50.625$ lbs., $g = 32.16$ f. s., $\omega = \frac{\pi}{9} = 0.34907$ sq. ft., $p_0 = 2116.3$ lbs. per sq. ft., $v_0 = 1450.5$ f. s., and $\log N = 9.07834 - 10$. Applying these numbers we find

$$\tau = 19.86 \text{ seconds}$$

$$f = 292500 \text{ lbs. per sq. ft.}$$

The two formulas for f give practically the same result, as they should.

The expression for f considered as the force of the powder is

$$f = \frac{p_0 v_0 T}{273},$$

in which p_0 is the normal atmospheric pressure; v_0 (in this place only), the volume of the gaseous products of unit weight of the explosive under normal atmospheric pressure, and T the absolute temperature of explosion. Sarrau gives, for a mixture of nitroglycerine and guncotton, $v_0 = 707$ litres for one kilogram of the explosive, and $t = 3557°$.* If we take the foot and pound for our units we shall have $v_0 = 11.325$ cubic feet. Also, $T = 3557 + 273 = 3830°$, and $p_0 = 2116.3$ lbs. per square foot, which is the equivalent of 10333 kgs. per m². Therefore

$$f = \frac{2116.3 \times 11.325 \times 3830}{273} = 336360 \text{ lbs. per square foot,}$$

which is the pressure of the gases of one pound of the explosive at temperature of combustion, confined in a volume of one cubic foot. A comparison of this value of f with that given by our equation shows that thirteen per cent. of the force was expended in doing work other than that of imparting energy of translation to the projectile and charge. This agrees almost exactly with other estimates of the non-useful work performed by the powder gas, based both upon practice and theory.†

The writer has no data with which to determine directly the accuracy of the computed value of τ for the Maxim-Schüpphaus powder. We may however compare the computed rates of burning of this powder for different pressures (which depend directly upon the values of τ), with those deduced by Vieille from his well known experiments with different kinds of colloidal powders. For this purpose we take equation (3) which, by making $l_0 = 0.03$ inch, $\tau = 19.86$ seconds and $p_0 = 14.6967$ lbs. per in², becomes

$$\frac{dl}{dt} = 0.00010278\, p \textit{ inches per second},$$

when p is in pounds per in². If p is given in kgs. per cm² the expression for the velocity of burning becomes

$$\frac{dl}{dt} = 0.0037129\, p \text{ cm. } \textit{per second}.$$

For a pressure of 3556 kgs. per cm² (which is about the maximum pressure found by experiment in the 8-inch B. L. Rifle), the velocity of burning by the last formula is 13.20 cm. per second, while Vieille's experiments gave for another kind of colloidal powder, 16.65 cm. For cordite and ballistite the experimental velocities were still greater.

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* *Memorial des poudres et Salpêtres*, for 1894. Page 221.

† *Interior Ballistics*. Page 137.

Since the factor A in equation (22) is independent of all the elements of loading its value may be found from a single measured muzzle velocity as shown by equation (24), namely,

$$A = \left(\frac{w'}{\tilde{\omega}}\right)^{\frac{1}{2}} V \operatorname{cosec} \varphi\,;$$

and this value of A substituted in the equation for the velocity,

$$v = A\left(\frac{\tilde{\omega}}{w'}\right)^{\frac{1}{2}} \sin \varphi,$$

gives a general expression for the velocity, for the same gun and kind of powder, which may be used for determining the velocity of the projectile at any point in the bore (where the powder is all converted into gas) for different charges and weights of projectile. It will be seen that the velocity varies inversely as the square root of the weight of projectile; but not, as would seem at first glance, directly as the square root of the charge, since this latter enters implicitely into sin φ. Taking, at the muzzle, $V = 2020$ f.s., and $u = 204.89$ inches, whence

$$x = \frac{204.89}{54.0086},$$

we find

$$A = 10679.8$$

The general expression for the velocity in that part of the bore of the 8-inch B.L.R. where the powder is all converted into gas, when loaded with the Maxim-Schüpphaus powder previously described, is, therefore,

$$v = 10679.8\left(\frac{\tilde{\omega}}{w'}\right)^{\frac{1}{2}} \sin \varphi \qquad (34)$$

or, writing for sin φ its value in terms of x,

$$v = 10679.8\left(\frac{\tilde{\omega}}{w'}\right)^{\frac{1}{2}}\left\{1 - \frac{1}{(1+x)^{\frac{1}{6}}}\right\}^{\frac{1}{2}}$$

Similarly we find the general expression for the pressure in pounds per in^2, for the conditions specified above, to be

$$p = \frac{5880\,\tilde{\omega}}{z_0(1+x)^{\frac{7}{6}}} \qquad (35)$$

To test these general expressions for velocity and pressure we will take Lieutenant Wheeler's fifth shot which was fired with a charge of 52 lbs. of Maxim-Schüpphaus powder, to which was added 0.625 lbs., of rifle powder as an igniter. We therefore have $\tilde{\omega} = 52.625$ lbs., and $w' = 300 + 26.3125 = 326.3125$. The total travel of the projectile in the bore was 204.97 inches. From these data we find by formulas heretofore given, $z_0 = 53.315$ inches, $x = 3.8445$ and $\log \sin \varphi = 9.68203$. Therefore by equations (34) and (35) we find

$$V = 2062.4 \text{ f.s.}$$

$$p = 11051 \text{ lbs. per in}^2.$$

The experimental muzzle velocity was 2062 f.s., and corresponding pressure on breech-block 11450 lbs. per in^2.

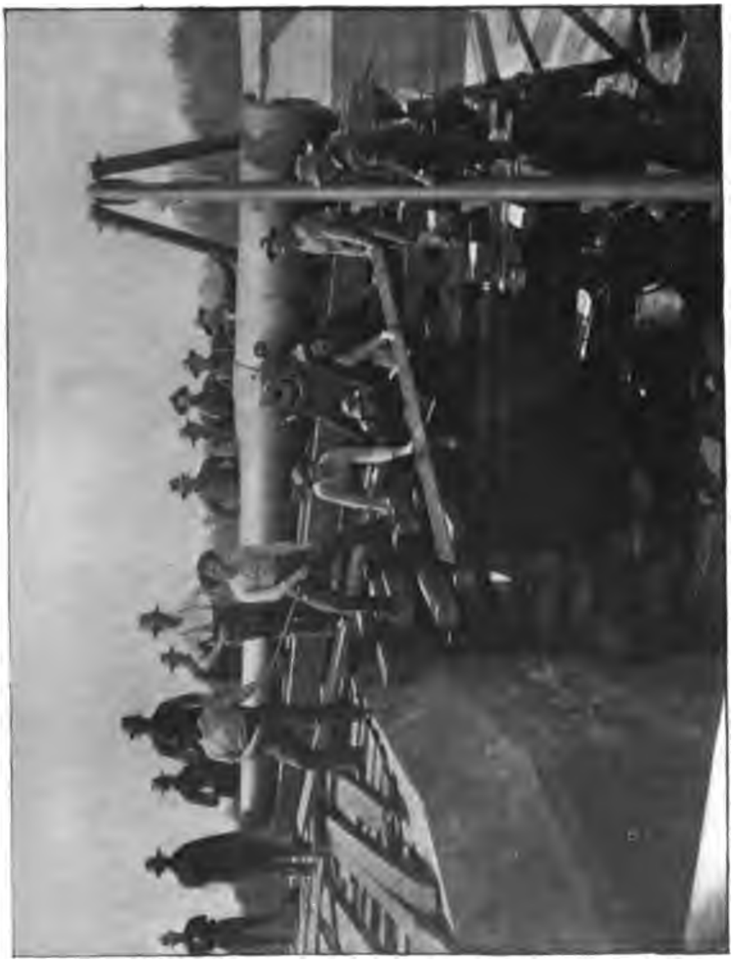
(To be continued.)

Captain James M. Ingalls, 1st Artillery,
Instructor.

THE MOUNTING OF 8-INCH B.L. RIFLES AT FORT WADSWORTH, NEW YORK HARBOR.

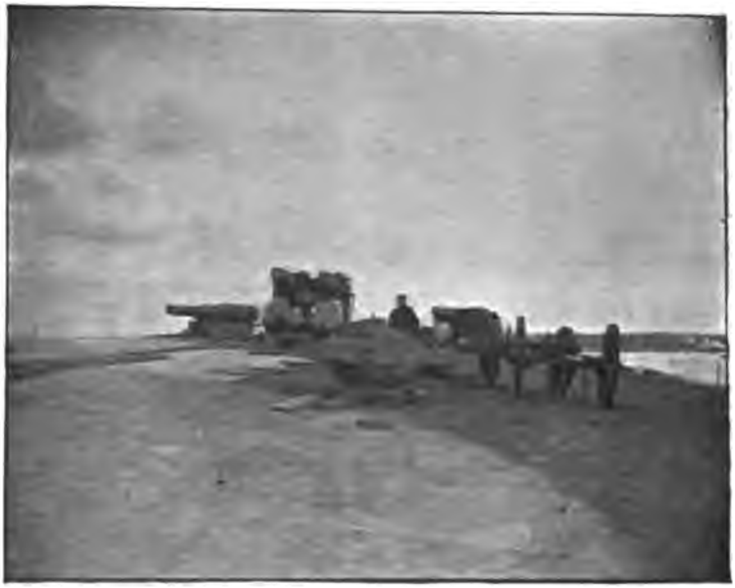
The photographs show portions of work in mounting four 8″ B. L. rifles at Fort Wadsworth. These guns and their carriages were landed at the Engineer dock, distant about three-fourths of a mile from the emplacements, and all material had to be hauled to the top of the parapet, which was about the 140-ft. level. The racers, or body of the carriages, were upon cradles when received. Rollers and way planks were placed in position for them and they were swung from the lighters and lowered on to the rollers prepared for them. Two of the guns were provided with cradles, and the other two gun cradles were made at the post by bolting large 15″ gun skids together and trimming the lower front edges off with an adze. All the other parts were transported on cradles made of old flank casemate chassis, or heavy skids bolted together, and heavy chains were passed and secured around them. All these cradles were put into position on the dock and the several parts, such as lever arms, gunners platform, counterpoise weights, etc., were lowered on to them by the steam derrick

of the lighter. This work was commenced on the 13th of February, 1896. After the carriages and their parts (which were received on the same day) had all been hauled from the dock,



the guns arrived and were hauled off the dock. The pintle rings were first hauled up to the top of the parapet in front of

their respective emplacements and then turned over to the Engineer Department. Work was then commenced on hauling the 19 cradles and their burdens to their respective positions. Three capstans were used, and placed at equal distances apart, and the carriages hauled up to one capstan, then taken hold of by the next capstan, until every cradle was drawn as close as possible to the preceding one, then the capstans in rear were moved to the front and placed at convenient distances apart, when the work proceeded as before, until the inclined skid-way on the exterior slope was reached, when by means of a capstan at a convenient distance, with the fall secured at top of parapet leading through a snatch-block on the parapet and thence back to the capstan. All the material was hauled to the top of the parapet and distributed by means of another capstan on the top as near as practicable to their several emplacements. There not being material enough on hand at the time belonging to the Ordnance Department, timbers belonging to the Engineer Department and formerly used as a tramway for conveying concrete, were used in making the cribbing on which the carriages were hauled; the latter were then lowered to their places and the guns mounted. All this work was done by the Ordnance Sergeant and two non-commissioned officers, and 18 men detailed from the three batteries, "C," "D" and "L," 1st Artillery, stationed at



the post, and after everything was well under way on its way up to the fort, two horses were used on the capstans. The winter storms delayed the work considerably; the whole forenoon being often spent in clearing away snow and cutting down drifts. The first gun was mounted on the 22nd of April, the second on May 4th, the third on May 14th, and the fourth on May 26th.

Captain R. H. Patterson,
First Artillery.

PROFESSIONAL NOTES.

ORGANIZATION.

The Development of the Japanese Army and Navy.

The great development in industrial undertakings and in the mercantile marine of the Japanese, to which we have from time to time directed attention, is being accompanied by a corresponding development of their military and naval strength. We are not greatly concerned with the former, except as a factor in the great changes which are taking place in the Land of the Rising Sun, and will, therefore, only note a few figures which show the proposed increase during the next 10 years. The following gives the numbers in in the standing army, and what they will be in March, 1906, if the plan which has been approved by the Imperial Diet be fully carried out:

	Present Numbers.	Numbers in 1906.
Officers (commissioned)	3,492	6,870
Officers (non-commissioned) . .	7,260	14,887
Rank and file	63,189	122,313
Total	73,941	144,070

If to the latter are added the reserves and Landwehr, the Japanese army in 1906 will number over half a million men. It may surprise the military authorities in this country to know that the estimates for the annual cost of maintenance of this force only amount to about 26 million yen, or about 2¾ million pounds sterling, and unless there is a great increase in the expenses of living during the next 10 years, this estimate is justified by past experience. The Japanese have therefore not only the advantage of lower cost of production in manufactured goods, but also in maintenance of their military forces.

The development of the Japanese navy is of more general interest to our readers than that of the army, as it is likely to involve a considerable amount of work for British shipbuilding yards. Before the recent war with China, the Japanese navy consisted of 33 ships of all classes, and over 40 torpedo-boats of various sizes, and in addition a few training ships and yachts which were not supposed to be of use for war purposes. Four of the above mentioned 33 ships were wooden sailing vessels employed chiefly for training purposes. Of the others, one was an armorclad, three were cruisers with small belts of armor at the water line; seven were fast steel cruisers of modern construction, protected by deck armor; six were steel unprotected cruisers; one was a torpedo-boat of modern type, and 10 were composite or wooden sloops and gun-vessels. We need not meantime go into any details of the more important of these vessels, as we have from time to time described them as they were built in this country, and no doubt those who are specially interested in the subject have noted their chief peculiarities. Together they formed, if not a very large, still a most effective fleet, as their action against that of China showed, although it is well known that the victories of the Japanese were owing not so much to the superiority of their ships as to the skill displayed in their management and the daring of their officers, as compared with the ignorance and inefficiency of the Chinese. The result of the war was that over a dozen vessels of different kinds were captured from the Chinese, and these, although much damaged, are being repaired and will make a considerable addition to the strength of the Japanese navy. In addition to all this, at the same time there were building in Japan three fast cruisers of the most modern type, and in this country two large battleships, which have since been launched and rank among the first-class battleships in the world.

The success of the war with China, however, incited the Japanese to aim at becoming one of the great naval powers of the world, and one of the subjects which engaged the attention of the government and of the people generally on the conclusion of the war, was the best means of increasing their navy. We have mentioned some of the industrial projects which were sanctioned during the last session of the Imperial Diet. After enumerating the more important proposals for promoting national progress in the fields of industry, communications, and education, the Emperor in his speech from the Throne said: "As to the defenses of the country, it has ever been our intention to complete them by degrees. Desirous of repairing the injuries occasioned during the recent hostilities, and of making necessary provisions for self-protection, we have charged our advisers with the task of elaborating the measures to be adopted. We have further ordered them to seek the Diet's approval for the outlays involved in carrying out these measures. We are confident that our good and loyal subjects will be only too glad to bear whatever increase of their public burden is thereby entailed." So much enthusiasm, indeed, prevailed among the Japanese on the subject of the development of the army and navy, that the only criticisms which were made on the proposals of the goverment were that they were insufficient to meet the aspirations and needs of the nation.

At the time the Diet sanctioned the proposals, a general idea was given of their extent, but recently more details have been published regarding them, a few of which may here be noted. According to these, the work is to be divided into two programmes, the first of which is intended to be completed in 1902, and includes 54 vessels of all kinds, with an aggregate displacement of 45,890 tons; the second includes 63 vessels with an aggregate displacement of 69,895 tons, or a total of 115,785 tons. The two programmes tabulated are as follows:

Japanese Naval Programmes.

——	First Programme.	Second Programme.	Total
Ironclads	1	3	4
First-class cruisers . . .	2	2	4
Second-class " . . .	3	—	3
Third-class " . . .	—	2	2
Torpedo gunboats . . .	1	2	3
" tenders	—	1	1
" destroyers . .	8	3	11
First-class torpedo-boats	5	18	23
Second-class "	28	3	31
Third-class "	6	29	35

The vessels to be built at home and abroad are as follows:

	Built at Home.	Built Abroad.
Ironclads	1	3
First-class cruisers	2	2
Second-class cruisers	2	1
Third-class cruisers	2	—
Torpedo gunboats	2	1
" tenders	—	1
" destroyers	7	4
First-class torpedo-boats	19	4

The arrangements for the building of the smaller torpedo-boats are not yet determined, and will depend on circumstances, especially on the development of shipbuilding facilities in Japan. It is expected that, at latest, the whole programme will be completed by April, 1906, but in view of the rapid progress which is being made in shipbuilding in Japan, it is probable that the period ot completion may be hastened more or less, and that subsequent to 1902 the strength of the Japanese navy will be most materially increased. By that date it is expected that Japan will be in possession of a navy which in point of displacement will more than equal the combined squadrons of Great Britian, Russia, France, Germany, and the United States, taking them at their present strength. But it is not at all likely that the governments of those countries will, under the new conditions of Japan, be content with that, so that by the date named there will be in the waters of the Far East sufficient explosive material to cause a great upheaval, which may probably revolutionize existing conditions of trade. British shipbuilders are therefore interested in the subject, not only on account of the possibility of orders for ships, but the British people are even more concerned with it on account of the potentialities involved in it. It is reported that at least two of the cruisers for the Japanese navy will be built in the United States, and that one will probably go to Cramp's, and the other to the Union Works of San Francisco.

Before the recent war the total expenditure of the Japanese on the naval department, including schools and administration, was only about 5½ million yen or about 600,000*l.* sterling per annum. Even during the current financial year the ordinary naval expenditure is only a little over 7½ million yen, or less than 800,000*l.* sterling. The extraordinary expenditure is to be spread over the period for which the programmes are drawn out. In this connection it is interesting to quote from the last edition of Brassey's *Naval Annual* the following estimated expenditure for 1895-6 of the principal naval powers.

British Empire	18,701,000
France	10,814,648
Russia	6,102,612
United States	5,073,365
Germany	4,818,125
Italy	3,713,569
Japan	1,127,974

The figures for Japan include, we suppose, the part of the extraordinary expenditure due for the year, and comparing them with the others, they are apt to cause some serious reflections. We are spending a far larger amount on our navy than any power in the world, in fact, more than the two next highest together. The question will naturally be asked, are we obtaining as good a return for our money as the others? The Japanese may possibly feel that in this respect they are ahead of us, but the requirements to be filled by the Japanese navy and our own differ so widely that no direct comparison of value can be readily made.

—*Engineering*, September 25, 1896.

ARTILLERY MATERIAL.

a. Guns and Carriages.

Present Condition of Foreign Field Artillery Armament as Regards Pieces for Curved Fire and Torpedo Shells.

Under the title "*Tir courbe ou obus brisantes?*" (Curved fire or torpedo shells?), the *Revue* recently gave an analysis of an Italian article in which the author, Major Mariani, examines the means at the disposal of field artillery for firing against sheltered troops. Three solutions present themselves; they involve respectively the use of

A howitzer or a field mortar;

A time torpedo shell with thick walls and a relatively feeble bursting charge;

A percussion torpedo shell with relatively thin walls and a bursting charge as heavy as is possible.

With a view to determining the question it would appear interesting to look into the present condition of the armaments of the foreign powers from these different points of view.

The information collected in these researches is as follows:

GERMANY.

Pieces for curved fire:—The German artillery has no howitzer or field mortar properly speaking. But the question of curved field fire has long been a matter of study in Germany.

In February, 1892, the *Revue* gave an account of firing experiments which had just been made with field mortars united in batteries. These experiments seem to have been successful but still did not lead to the adoption of pieces of their kind.

Quite recently the *Allgemeine Militär-Zeitung* (No. 73, September 12th, 1895) alluded to the adoption in the near future of a 12 c. (4.72 in.) field howitzer: Here is the translation of the passage: "Admitting that in modern war certain of the objectives which will be met in a campaign can only be reached successfully by means of pieces for curved fire, the question of the expediency of adopting a piece for curved field fire—howitzer or mortar, is being very warmly discussed in military circles. To completely carry out its object, such a piece should be capable of being maneuvered without difficulty by field artillery troops and therefor should, as far as possible, be similar to the field pieces now in use. With these ideas in view a 12 c. (4.72 in.) field howitzer is to be tried."

As a note in this question of field curved fire it is proper to mention the 15 c. (5.9 in.) howitzer and the 21 c. (8.3 in.) mortar which are intended for the foot artillery with teams (*Fussartillerie mit Bespannung*).

The role of these pieces has been indicated in the *Revue d' Artillerie* (Nov., 1895). The 21. c. (8.3 in.) mortar is so heavy that it is necessary to carry it separated from its carriage on a mortar wagon (*porte-corps*) which when loaded weighs about 4,500 kg. (9,920 pounds); it has therefor nothing in common with a field weapon.

The 15 c. (5.9 in.) howitzer is much more like a field piece. The piece on its carriage weighs 2,600 kgs. (5,732 pounds); this weight is of course very high for a vehicle which must be able to move off the roads, still it is not inadmissible since it is about the same as that of the field caisson when the six cannoneers are on the chests. (German caisson with six cannoneers: Model 73, 2,620 kg. (5,776 pounds); model 88, 2,515 kg. (5,545 pounds).

Torpedo Shells:—The solution adopted in Germany is the time torpedo shell with thick walls and a relatively feeble bursting charge. This shell is of steel; it weighs 7.5 kg. (16½ pounds), contains 170 grammes (6 ounces) of explosive material* and gives about 500 fragments. It is a relatively short projectile; its length, including the fuse, is but 2.6 calibers. The opening of the sheaf is of 110°; in the interior of this sheaf is an empty zone which corresponds to an angle of opening about equal to 90°. The projectile is provided with the same double effect fuse as the shrapnel and is graduated up to 4,500 m. (4,366 yds.). The same firing tables serve for both projectiles. Each battery has in its chests 885 rounds. Of this total 150 rounds are torpedo shell, making about 17% of the whole.

ENGLAND.

Pieces for curved fire:—No piece of this nature has as yet been adopted in England; but "for some years the question of howitzers intended for siege parks or for *field batteries* has been under consideration.† A 5-inch field howitzer weighing 610 kg. (1,342 pounds), was first contemplated; at present the trials are of a "4.7 in. (11.8 c.) field howitzer. During the firing this piece recoils by sliding in a sleeve or jacket, while the carriage anchors itself in the ground."‡

Torpedo Shells:—The English field artillery has no torpedo shells.

AUSTRIA-HUNGARY.

Pieces for curved fire:—There exists no field howitzer or mortar, properly speaking.

The question of pieces for curved fire for field use has passed in Austria through several phases.

The Technical Military Committee had trials made some years ago of a 12 c. (4.7 in.) bronze-steel field howitzer.§ But the studies relative to a special field equipment of large caliber seem to have been if not entirely abandoned at least in a measure set aside because of the adoption of the 15 *c.* (5.9 in.) *battery howitzer.* This piece seems destined to play a somewhat extended role not only as a siege and position weapon but also in a certain measure as a field howitzer.§ Here is the translation of a passage from V. Löbell's Jahresberichte relating to this subject.‖ "The trials of the 12 c. (4.7 in.) field howitzer have been stopped. The idea of introducing pieces of this character in the field artillery has therefor been given up. For the cases where field operations require the use of curved fire, the 15 c. (5.9 in.) mortars or howitzers of the groups of mobile siege batteries are counted upon."

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* Granatfüllung c/88. See *Revue d' Artillerie*, Vol. 45, Oct., 1894, p. 9.

† Treatise on Service Ordnance, 1893, p. 316.

‡ Willie, Waffenlehre, 1896, p. 423.

§ See *Revue d' Artillerie*, V. 44, June 1894, page 266; and V. 39, Maruh 1892, page 551.

‖ See von Löbell's Jahresberichte über die Veränderungen und Fortschritte im Militärwesen, 1894, p. 410.

Again General Wille in his work entitled *Waffenlehre*[*] says that "the construction of a 12 c. (4.7 in.) howitzer intended for the Austrian field artillery has been abandoned, and gives besides the following information on the present organization of the *groups of mobile siege batteries* in Austria. "There exist in Austria five groups of mobile siege batteries; each of these comprises three batteries and a park of siege ammunition; each battery contains four battery howitzers. To each group is attached a company of fortress artillery which on a peace footing, for mounted instruction and maneuvers with harnessed pieces, disposes of the following personnel: 18 drivers, two saddle horses for officers, two saddle horses for non-commissioned officers, 16 draft horses and two spare horses."

The following data, borrowed from Captain Kortzen's Manual,[†] completes in certain points the information which the *Revue* has already furnished on the battery howitzer destined for the groups of mobile siege batteries. The battery howitzer is of bronze; its caliber is 15 c. (5.9 in.); its weight, including the breech block, is 1,130 kg. (2,491 pounds). It is mounted on a carriage (*affût de batterie*) which brings the height of the muzzle 1.40 m. (35 in.) from the ground; this carriage with all its accessories weighs 1,350 kg. (2,976 pounds). The weight of the limber is 400 kg. (881 pounds). The battery howitzer fires:

Ordinary shell, model 1880, weighing 31.9 kg. (70 pounds).

Shrapnel, model 1880, weighing 36.9 kg. (81 pounds), with fuze model 1893.

Canister.

There are four different charges of smokeless powder which weigh respectively, 260 grammes (9 oz.), 350 grammes (12 oz.), 460 grammes (1 pound), 750 grammes (26 oz.), and give velocities which vary with the ordinary shell between 164 m. (538 ft.) and 291 m. (954 ft.), and for the shrapnel, between 56 m. (512 ft.) and 276 m. (905 ft.).

It is to be observed that Austria has never lost sight of the necessity for assuring means of curved fire to field pieces. She retained for a long time in the stores of ammunition for her field batteries a certain proportion of reduced charges or cartridges for plunging fire called Wurfpatronen.[‡] She afterwards made use of cartridges in two parts.[§]

It is only recently and since the adoption of smokeless powder, model 1893, that the 9 c. (3.5 in.) field cannon has used a charge of but one weight, 440 grammes (15½ oz.).

Torpedo Shells:—A shell loaded with ecrasite was adopted in 1894 for the light batteries of the field artillery.[‖] This projectile weighs 7.250 kg. (15¼ pounds); it is armed with a double action fuze; its initial velocity is about that of the ordinary 9 c. (3.5 in.) shell, that is about 445 m. (1,460 ft). The troops do not yet appear to have received their entire supply of torpedo shells.

According to the estimates of the budget for 1896, each mounted battery should have, per piece, 15 shells of this model in place of the same number of ordinary shells.

Under these conditions, each mounted Austrian battery having eight pieces, and having in its chests 1,024 rounds, the supply of torpedo shells will be 11.7% of the total supply.

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[*] Wille, *Waffenlehre*, 1896, pp. 103, 104.

[†] Kortzen, *Tackenbuch für Artillerie Offiziere*, 1895.

[‡] See *Revue d' Artillerie*, v. 39. Nov., 1891, p. 118.

[§] See *Revue d' Artillerie*, v. 46. April, 1895. p. 7.

[‖] See *Revue d' Artillerie*, v. 46. Aug., 1895, p. 518.

Ecrasite is an explosive having for its base picric acid. According to the *Dictionary of Explosives* of Cundill and Thomson it is composed of trinitrocresylate of ammonia and of nitrate of potash. It is employed in a melted state in projectiles, and in a compressed form in petards. To explode it a detonator of gun cotton is generally used. Ecrasite is slightly hygrometric, but stable and very little affected by heat or by mechanical causes such as shock, friction, etc. The bursting cloud which it makes is of a dark color. Its explosive power is about $\frac{10}{7}$ that of dynamite.

BELGIUM.

Pieces for curved fire:—The Belgian artillery has no field howitzer or mortar.

There exist, to be sure, in the siege parks two weapons light enough to fulfill, should they be required, the role of field pieces: A 15 c. (5.9 in.) mortar which fires, with a charge of 1.6 kg. (3½ pounds) projectiles weighing 31.5 kg. (68 pounds, 7 oz.), and a 9 c. (3.54 in.) mortar, which, with a charge of 300 g. (10½ oz.) throws projectiles weighing 6.8 kg. (15 pounds).* But nothing in the organization of the carriages and material for these mortars implies an idea of their possible utilization for field operations.

The field artillery is armed with 7.5 c. (2.95 in.) and 8.7 c (3.42 in.) cannon. Until the present time, at least as far as we know, the Belgian field artillery used only black powder without fractional charges. The recent publication (1895) of the "*Aide-Mémoire de Manoeuvers et de Campagne*" by Lieutenant-General Fix has led to a modification of this view. General Fix does not give any details of the composition of the charges used in the field batteries, but he indicates what the loads of the artillery ammunition columns are, and these indications lead one to think that Belgium has adopted for curved field fire the solution that has long been adopted in Austria, that of reduced charges; for according to the above mentioned work,* each 9 c. (3.54 in.) caisson of the ammunition columns contains 100 charges of 700 g. (1½ pounds) 18 *small* charges of 470 g. (1 pound) and 18 *small* charges of 310 g. (11 oz.); each 8 c. (3.15 in.) caisson contains 108 charges of 530 g. (1 pound, 2 oz.) 15 *small* charges of 330 g. (11.6 oz.) and 15 *small* charges of 200 g. (7 oz.). This evidently means charges of smokeless powder. The large charges, which, by the way, correspond in number to the total number of the projectiles, are intended for normal fire; the small charges are extra and are without doubt to be reserved for special cases where a plunging fire shall be judged useful.

Torpedo Shells:—There are no torpedo shells.

BRAZIL.

Pieces for curved fire:—The question of field pieces for curved fire has recently been discussed in Brazil on the occasion of an offer made by the firm of Krupp to Colonel de Medeiros, president of a purchasing commission sent to Europe by the Brazilian government.

The propositions of Krupp related to 30 field howitzers of nickel-steel capable of firing torpedo shells. Colonel de Medeiros had transmitted the propositions to the Brazilian Minister of War, joining in support of them a report giving the history of the question of torpedo shells and had called attention to the fact that the Argentines, eventual adversaries of the Brazilians, were increasing their field artillery and adding to it pieces intended for this special fire.

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* *Aide-Mémoire de Manœuvres et de Campagne.* By Lieutenant-General H. C. Fix. pp. 145 and 146.

The views of the proper authorities were unfavorable to the propositions, they were in part based as follows :[*]

"Field warfare will be conducted in general very differently in South America from what it will be in Europe; we will have to modify the tactics of marching as well as those of combat, if not in principle at least in the details. For this and other special reasons it does not seem necessary to us to introduce into our army this proposed innovation which would be for us a source of difficulties and dangers, and which might compromise the mobility and service of our field artillery. Besides, the artillery is already able to fire projectiles charged with high explosives with its *ordinary means of propulsion*; it is not necessary to have recourse to particular weapons such as pneumatic guns, cannon made of special metal, bronze or steel, for the purpose of resisting the violent effects of premature explosions. It is therefor useless to adopt cannon of nickel steel of which the price is higher than it is for pieces of ordinary steel."

Torpedo Shells:—Torpedo shells do not exist in the Brazilian field artillery.

BULGARIA.

Pieces for curved fire:—A 12 c. (4.72 in.) field howitzer on the Krupp system[†] is in use in the Bulgarian artillery.

A battery of these howitzers is attached to each of the divisions of the active army.[‡]

Torpedo Shells:—There are no torpedo shells.

DENMARK.

Pieces for curved fire:—The acquisition of 12 c. (4.72 in.) howitzers on field carriages is talked of.[§]

Torpedo Shells:—As regards torpedo shells, trials are in progress; but they do not seem to bear on a field projectile.

SPAIN.

Pieces for curved fire:—Under a royal decision of April 20th, 1893, fixing the models for the regulation cannon, a mortar and a howitzer are assigned to siege, fortress and *field* service.[‖]

The mortar, called 9 c. (3.54 in.) mortar, model 1892, is of bronze-steel and is on the Mata system; its caliber is 8.7 c. (3.42 in.), its weight 81 kg. (178½ pounds). It fires, with a charge of 370 g. (13 oz.), an ordinary shell weighing 6.3 kg. (13 pounds, 14 oz.) and a shrapnel weighing 7.1 kg. (15 pounds, 10 oz.), giving an initial velocity respectively equal to 219 m. (718½ ft.) and 200 m. (656 ft.).

The howitzer, still under consideration, is also of bronze-steel; its caliber is 12 c. (4.72 in.), its weight 600 kg. (1,322 pounds). It fires with a charge of 1.8 kg. (4 pounds), an ordinary shell and a shrapnel, each weighing 18 kg. (39 pounds, 9 oz.).

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[*] *Revista da Commissão Militar Consultativa*. 1895, Nos. 4 and 5.

[†] See V. Löbell's *Jahresberichte*. 1894, p. 405.

[‡] See *Revue d' Artillerie*, v. 46, August, 1895. p. 522.

[§] See V. Löbell's *Jahresberichte*. 1894, p. 414.

[‖] D. J. de Ugarte, *Libro de Memorias del Oficial de Artilleria*. 1895, p. 207.

Torpedo Shells:—The Spanish field artillery has no torpedo shells.

UNITED STATES.

Pieces for curved fire:—A field mortar, model 1891, is in service in the United States.[*]

This mortar is of steel; its caliber is the same as that of the heavy field piece, 3.6 in. (9.14 c.), its weight is 244 pounds (111 kg.). It fires, with a charge of 1 pound (453.6 g.), the same projectile as the cannon—a shell and a base charged shrapnel. These projectiles weigh 20 pounds (9.07 kg.), and have an initial velocity of about 650 ft. (198 m.). The carriage has no wheels. The mortars are transported by pairs on special wagons; their unloading and placing in battery require three minutes and ten seconds.

Torpedo Shells:—The field artillery has no torpedo shells.

ITALY.

Pieces for curved fire:—Italy has no field howitzer or mortar, properly speaking. Major Mariani's article leaves no doubt on this point, although, according to Colonel Witte, Italy has, following Russia's example, had trials of field mortars which seem to have ended in the adoption of pieces of this nature.[†]

But the Italian artillery has in its siege parks weapons which seem able should the need arise to fulfil the role of field pieces for curved fire. She possesses notably a 9 c. (3.54 in.) mortar[‡] which may be carried on mule back and which appears to be intended to act in first line against the entrenchments which are met with in mountain warfare. This mortar is of compressed bronze; its caliber is 8.7 c. (3.42 in.), its weight 110 kg. (242½ pounds).

It fires, with charges varying between 50 and 200 g. (1.7 and 7 oz.), an ordinary shell weighing 6.76 kg. (14 pounds, 14 oz.), a shrapnel "à diaphragme" weighing 6.916 kg. (15 pounds, 4 oz.), a canister weighing 7.125 kg. (15pounds, 1 oz.), and a torpedo shell recently adopted which weighs 8.8 kg. (19 pounds, 6 oz.), and contains 1.8 kg. (4 pounds) of eversite.[§]

This explosive has for its base picric acid. The weight of the carriage is 125 kg. (275 pounds, 9 oz.).

It is also to be observed that the 9 c. (3.54 in.) field gun uses three different charges of filite;[‖] the first is the ordinary charge of 460 g. (1 pound), the second,. stronger than the ordinary charge and permitting of an increased range in certain particular cases, is of 570 g. (1 pound, 4 oz.), finally the third is a charge *reduced for plunging fire* and weighs 255 g. (9 oz.).

Torpedo Shells:—There are no torpedo shells for field guns, properly speaking.

JAPAN.

According to Major Mariani, the Japanese had for the siege of Port Arthur batteries of Krupp howitzers which permitted them "to accompany (with shell fire) the bayonets of their infantry almost up to the instant when they crossed them with those of the defenders," and to take by assault several works one may say at the first effort.

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[*] See *Revue d' Artillerie*, v. 41. March, 1893, p. 511.

[†] Witte, *Fortschritte und Veränderungen im Gebiete des Weffenwesens in der Neusten Zeit*, second part, p. 186, note 2.

[‡] See *Revue d' Artillerie*, v. 41. Oct., 1892, p. 30.

[§] See *Revue d' Artillerie*, v. 47. Feb., 1896, 544.

[‖] Filite has a composition analogous to that of balistite, i. e., equal parts of nitro-glycerine and of gun-cotton. It is employed in the shape of threads of square section, the length of which corresponds to the length of the cartridge; for field guns their thickness is 1 mm. The cartridge contains two little cylindrical caps of powder (filite) in sheets which serve to keep together the ends of the threads. See *Revue d' Artillerie*, v. 46. June, 1895, p. 328.

The *Army and Navy Gazette*, No. 1,636, of December 29th, 1895, also attributes the success of the Japanese in great part to the high angle howitzers with which their army was furnished. According to this paper these weapons had a relatively small caliber and fired projectiles weighing 36 kg. (79 pounds, 6 oz.). This information does not, however, permit us to conclude that field howitzers were in question; as for the attack on Port Arthur, the Japanese had at their disposal a siege park of which the pieces were placed in battery during the night which preceded the action at about 3,500 m. (3,827 yds.) from the Chinese forts.

RUSSIA.

Pieces for curved fire:—Since 1886 the Russian artillery uses a field mortar.

This weapon has a caliber of 6 in. (15.24 c.), its weight is 460 kg. (1014 pounds), and that of the carriage (including accessories) 680 kg. (1,499 pounds). This mortar was described in the *Revue* in 1895.[*] Russia will have by the end of the year 1886,[‡] 26 batteries of mortars, each comprising 6 pieces, 18 ordinary caissons, 6 two-wheeled caissons and 12 wagons (*voitures*) of different kinds.

Torpedo Shells:—Besides the "fougasse" shell loaded with powder and the base-charged shrapnel spoken of in the above mentioned article in the *Revue*, this mortar fires a "fougasse" shell loaded with "mélinite" (*melinitnouiow*) which is, as far as we know, mentioned for the first time in the Artillery Course, which has recently appeared, by Boudaevski.[§] Here is some information in regard to this projectile.

Its length is 3 calibers. The base is screwed on to the cylindrical part with which the ogive forms one piece; the latter is provided with an opening into which is placed, at the time for firing, a detonator armed with a percussion fuze. The bursting charge is 5.7 kg. (12 pounds, 9.6 oz.), the whole weight of the shell is 28.4 kg. (62 pounds, 9.7 oz.). According to Korzen,[‖] the field guns also fire a torpedo shell; the explosive is fluid at the time of loading the shells.

SWEDEN.

Pieces for curved fire:—The Swedish artillery has made a number of experiments, having in view ordnance of this nature, but the results have not been sufficiently conclusive to justify the adoption of a supplementary field piece. Besides Sweden has pieces of position intermediate between field and siege guns which may in a certain measure permit of curved field fire.

Torpedo Shells:—The question of the adoption of torpedo shells for field artillery has been studied in Sweden. Trials have even been made with a steel shell weighing 6.64 kg. (14 pounds, 10 oz,) loaded with gun-cotton. But the Swedish artillery committee have for the time being suspended these studies. Here are, according to the *Artilleri Tidskrift*, the reasons given in support of this decision:[**] "In Sweden and in the neighboring countries where the Swedish artillery may be called upon to act, the obstacles which the artillery will meet are not sufficiently resisting to require the creation of new weapons of which the manufacture and use present dangers. The defensive properties of the houses in particular are feeble and the projectiles will have passed through the walls before exploding. Besides, the fire with time torpedo shells of which the effect, though of extraordinary violence, is localized within a small radius, is so much at the mercy of an error in elevation or in the setting of the fuze that it seems preferable to hold to the use of shrapnel for firing against troops.[*]

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[*] See *Revue d' Artillerie*, v. 45. June, 1895, p. 519.

[‡] See *Revue d' Artillerie*, v. 47. Dec., 1895, p. 320.

[§] Boudaevski, *Cours d' Artillerie pour les Ecoles Militaires*. 1895.

[‖] Korzen, *Taschenbuch für Artillerie Officiere*. p. 285.

[**] *Artilleri Tidskrift*. 1893, No. 1, and 1894, No. 4.

SWITZERLAND.

Pieces for curved fire:—The field artillery has no howitzer or mortar, properly speaking. But the *position artillery* which in Switzerland constitutes a special *sub*-arm of the service, distinct from the fortress artillery[†] contains in each of the five groups of which it is composed 12 c. (4.72 in.) mortars mounted on *field carriages* with transportable platforms.

The pieces are of bronze or of steel.[‡] The weight of the bronze mortar is 631 kg. (1,390 pounds), that of the steel mortar 534 kg. (1,177 pounds). The carriages (*voitures-pièces*) weigh, including the platforms, respectively 2,208 kg. (4,867 pounds), and 2,111 kg. (4.654 pounds); the caisson weighs 2,362 kg. (5,207 pounds). Pieces and caissons are each drawn by four horses. The 12 c. (4.72 in.) mortar fires a shell and a base charged shrapnel, each weighing 18 kg. (39 pounds, 9 oz.).

Torpedo Shells:—There are no torpedo shells at present for field guns, properly speaking. A certain number of 12 c. (4.72 in.) shells which were in store have recently been turned into torpedo shells. A 12 c. (4.72 in.) steel torpedo shell is being studied.[§]

TURKEY.

Pieces for curved fire:—Turkey decided in 1895 to form two regiments armed with howitzers.[‖]

These pieces are on the Krupp system. Their caliber is 12 c. (4.72 in.).

Torpedo Shells:—There are no torpedo shells in the Turkish artillery.

A. MICHAUT, Major of Artillery.

In *Revue d' Artillerie*, Feb., 1896.

[Translated by Colonel JOHN BIDDLE PORTER.]

b. Armor and Projectiles.

The Trial of the Iowa Plate at Indian Head, September, 1895, and Krupp's Trials of 80-mm. and 100-mm. Armor Plates at the Proving Grounds near Meppen, October, 1895.

(Extract from an article by Captain J. Castner, first published in *Stahl und Eisen* April 1, 1896.)

In *Stahl und Eisen* of April 1st, 1896, Captain J. Castner publishes an article, which in connection with a former article by the same author containing the reports of trials of 300-mm and 146-mm Krupp armor plates (Stahl und Eisen 1. u. 15. 9. 1895) first mentions the *Iowa* trial which took place in the

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[*] With the shells experimented with the difficulty in setting the fuze was increased by the fact that the bursting cloud produced by gun-cotton is difficult to observe.

[†] See *Revue d' Artillerie*. v. 33. March, 1889, p. 587, and v. 36. July, 1890, p. 376.

[‡] *Taschenkalender für Schweizcrische Wehrmänner*, 1895, p. 93.

[§] See *Revue d' Artillerie*. v. 46. Sept., 1895, p. 632.

[‖] See *Revue d' Artillerie*. v. 45. Dec., 1894, p. 278.

United States September 1895 and then gives a minute report of the trials of 80-mm and 100-mm Krupp plates tested in October 1895 at the proving grounds near Meppen. Concerning the *Iowa* trial the author says: "The success, which was obtained in the United States, by reforging armor plates after carburisation and before the hardening process resulted in adopting this method for the manufacture of Harveyed armor plates for the United States battleships. (In a recent trial however, which took place in the United States, a reforged plate showed very bad results, which, to a certain degree, seems to throw doubt upon the value of this method.) It is the opinion that reforging the plates after the annealing process solidifies the plates and increases their power of resistance. The plates for the battleship *Iowa* therefore were made by this process at the Carnegie Works."

IOWA PLATE.

The trial of a plate representing a lot of 631 tons for the sides of the *Iowa* took place at the proving grounds at Indian Head September 1895.

"The plate was 4.9 m (16 feet 1 inch) long, 2.29 m (7 feet 6 inches) wide, 356 mm (14 inches) thick at the top and tapering from a point 1.22 m (4 feet) below to 178 mm (7 inches) at the bottom. It weighed 27.4 ton (27 English tons).

The plate was fastened to a backing, which was an exact reproduction of a section of the side of the battleship *Iowa*, including the protective deck and a supporing structure, whose power of resistance against the shaking effect of the shells should also be tested."

Here follows the description of the backing and the actual account of the trial, whose results are given in the accompanying table.

The author continues:

"The Americans are highly satisfied with this result and praise the quality of this plate as unexcelled hitherto. Still, they will have to submit themselves to a considerable restriction of their judgment, if we compare the results with those which were attained by a 300-cm. (12-in.) Krupp plate, March, 1895 (cf. *Stahl und Eisen* 1895, page 852 f.). Though a ratio of quality of the two plates cannot be given exactly in figures on account of their being of different thickness, it still can be shown by calculation that a 356-mm. (14-in.) plate of equal quality with the 300-mm. (11.8-in.) Krupp plate tested in March 1895 would under the same conditions have been perforated with a striking velocity of no less than 700 ms. (2296.6 fts.), while the Carnegie plate was easily perforated with a striking velocity of 500 ms. (1771.7 fts.)."

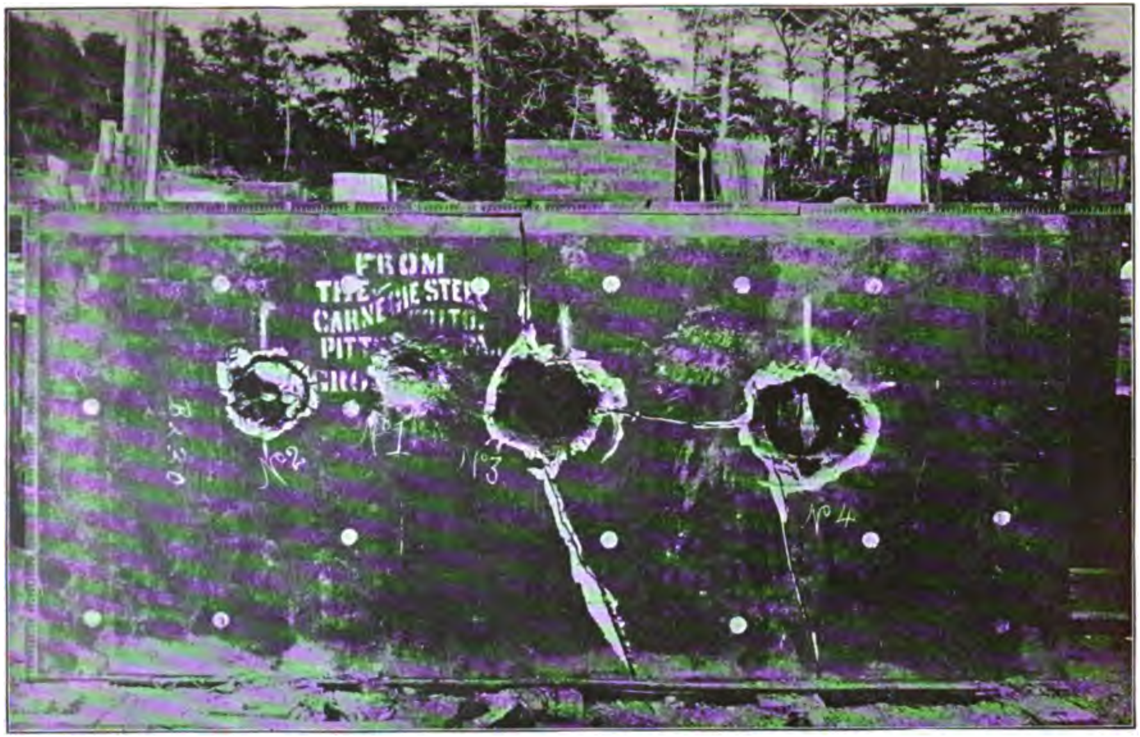
"This deduction however only shows the resistance of the Krupp plate against perforation, the quality of the plate is by no means fully characterised by it. A glance at the photographs of the tested Krupp plate will justify our supposition, that, even, had the projectile perforated, the plate would not have received a through crack, as the *Iowa* plate did which went entirely to pieces. This circumstance manifests, abstract from the higher power of resistance against perforation, a very considerable difference in quality in favor of the Krupp plate. For, while the latter would only have lost its protective effect on the point of impact, the *Iowa* plate, loosened in its fastening and split, probably could have been thrown down in pieces from the side of the ship by another hitting projectile of relatively small perforating power."

"This comparison also shows the other side of the opinion represented by a large party, that hardness should be the main quality of an armor, because it offers the best, if not the only security, to keep off the hitting projectiles.

No. of Impact.	Caliber of gun.	PROJECTILE.		Distance of plate from muzzle of gun.	Striking velocity.	Striking energy.	Thickness of plate which the shell would have perforated according to French formula.		Penetration of point of projectile	EFFECTS.	
		Kind.	Weight.				Ordinary Steel.	Iron.		On Projectile.	On Plate.
	cm. in.		kg. lbs.	m. yards.	m. f.s.	mt. fts.	mm. in.	mm. in.	cm. in.		
I	25.4 10	Carpenter A.P.	226.8 500	183 200	449 1472	2333 7529	308 12.13	442 17.40	102 4	broken.	no cracks.
II	"	"	"	"	567 1859	3720 12004	430 16.93	632 24.88	254 10	"	"
III	30.5 12	Wheeler Sterling A.P	385.6 850	"	549 1801	5930 19136	492 19.37	732 28.82	515 20.28	broken, point of projectile through the thin plating immediately behind the wood backing.	cracked from the upper to the lower edge of the plate and from impact No. III to impacts Nos. II and I.
IV	"	"	499 1100	"	548 1797	7673 24761	543 21.38	814 32.05	through	perforated the armor, the backing and the frame work and buried itself 12 feet in the sand butt behind.	cracked from the impact to the 30.5 cm. (12 in.) impact; another crack extended from the 33 cm. (13 in.) impact to the top of the plate and a fine crack reached from the same impact to the bottom of the plate.

Figure 1.

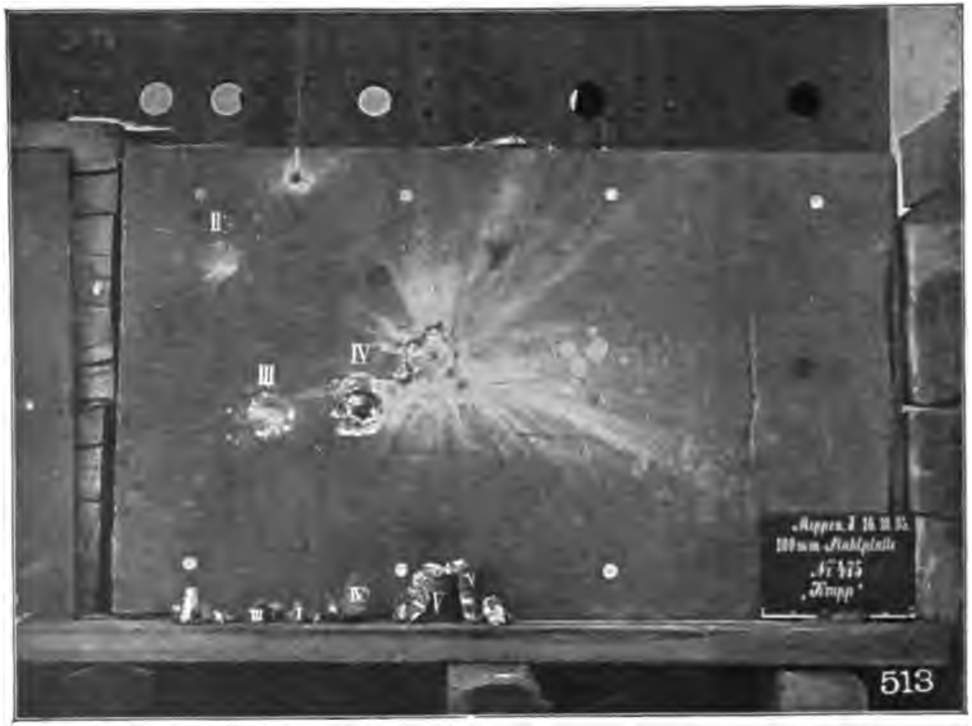
Carnegie 356 mm. (14-in.) reforged, Harveyed and face-hardened nickel steel plate for the Iowa.



Front of Plate.

FIGURE 2.

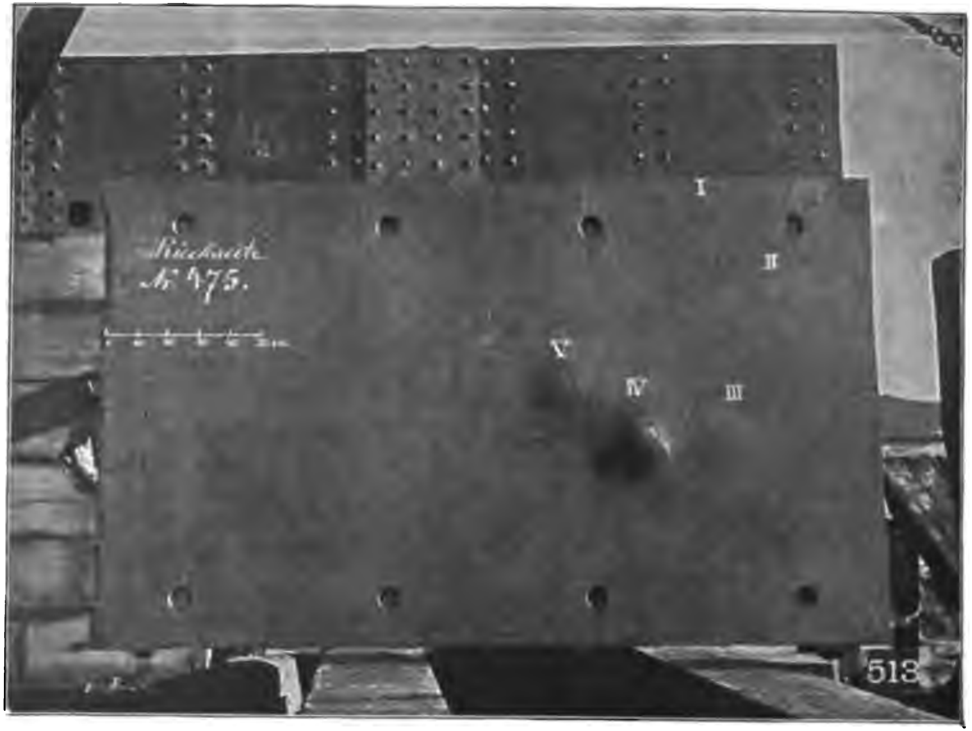
Krupp 100 mm. (3.9-in.) face-hardened nickel steel plate No. 475.



Front of Plate after 5 rounds.

FIGURE 3.

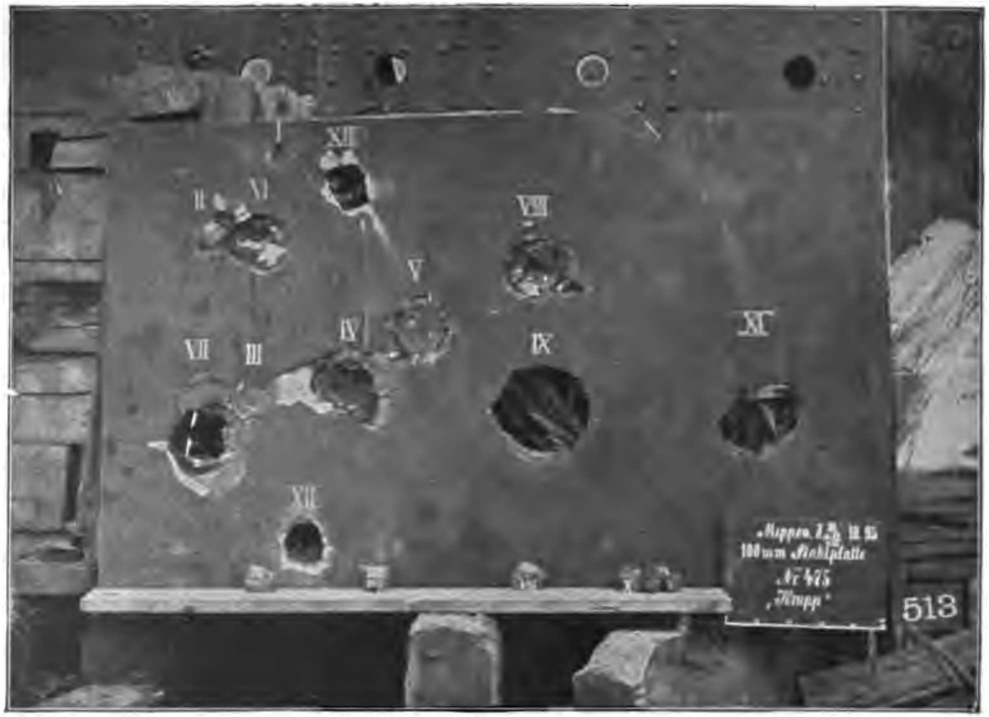
Krupp 100 mm. (3.9-in.) face-hardened nickel steel plate No. 475.



Back of Plate after 5 rounds.

FIGURE 4.

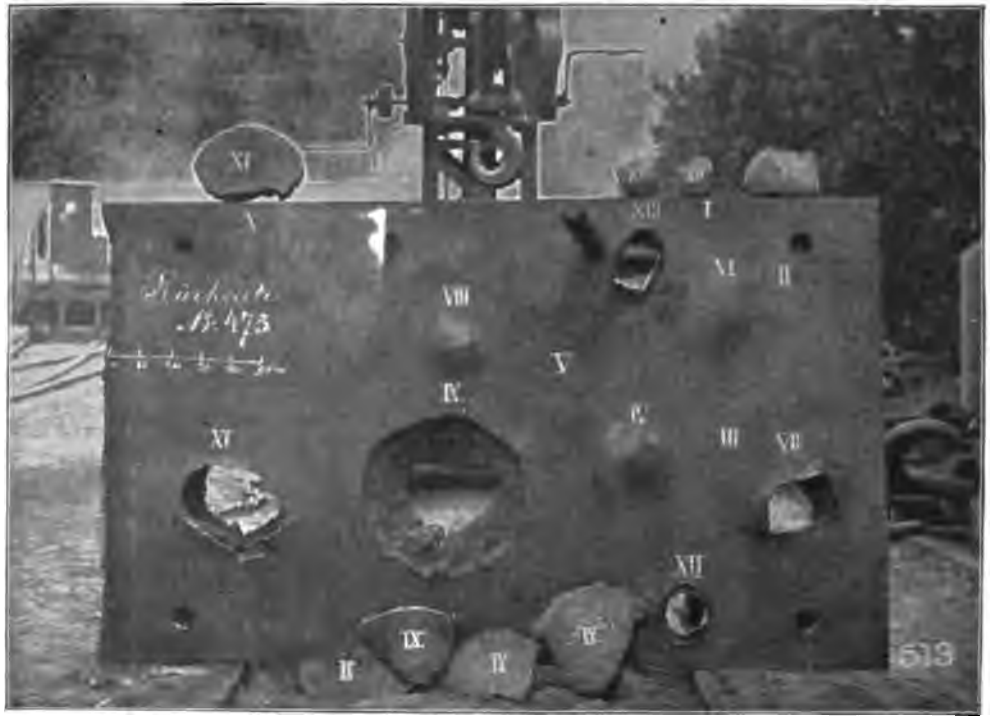
Krupp 100 mm. (3.9-in.) face-hardened nickel steel plate No. 475.



Front of Plate after 13 rounds.

FIGURE 5.

Krupp 100 mm. (3.9-in.) face-hardened nickel steel plate No. 475.



Back of Plate after 13 rounds.

It is pretended that the breaking of a plate is a smaller disadvantage, than the perforation, because it is not likely that the same plate should be hit more than once in a single engagement. But after the experiences of the battle of Yalu, where the Chinese battleship *Ting Yuen* was hit more than 200 times, this opinion can hardly be maintained. It is further to be mentioned, that, in order to prevent Harveyed armor from falling off in pieces from the sides of the ship, it must be fastened to the sides by a greater number of bolts, which means a considerable increase of weight. Plates which offer the security not to break when fired at, require for their fastening only a small number of bolts and in certain constructions, as ammunition hoists, etc., one can go so far as to set them up without bolts and backing."

"It needs not to be explained, what advantages are gained hereby regarding the necessity of saving room and weight."

"In our opinion the beau ideal of a plate must unite greatest hardness and corresponding toughness. The best American plates are still far from this ideal, because they lack toughness, while the Krupp plates stand considerably nearer to it, up to date the nearest. It seems strange how the American accounts of September, 1895, and later on, could speak of the unexcelled quality of the *Iowa* plate, since the Krupp trial had already taken place in March, 1895, and was published in the *Marine-Rundschau*, June, 1895, and therefore could have been known to the Americans when the *Iowa* plate was tested."

The author then mentions the recent trials of 80-mm. (3.2-in.) Krupp plates and continues:

"After excellent successes had been attained by 146-mm. (5.75-in.) and 300-mm (11.8-in.) plates, the question approached the Krupp Works, whether the new process applied to the manufacture of these plates should prove equally efficient for 80-mm. (3.2-in.) and 100-mm. (3.9-in.) plates. It was the more necessary to decide this question by ballistic trials, as on the one hand thin plates with hardened surface had shown a great predisposition to cracking, on the other hand plates of such small thickness and great power of resistance mean a great advantage, the necessity being acknowledged to provide all the quick-firing guns standing on the main deck of men-of-war with an effective armor protection.

* * * * *

"But not only guns are to be protected in modern cruisers, the stacks also and ammunition hoists cannot further remain without armor protection."

* * * * *

"Such an extensive application of armor on board of cruisers, can, for obvious reasons, only be possible, if the weight of the armor is kept in reasonable limits. The armor therefore, if it shall be of any protective value, must have a great power of resistance. In all these cases thin plates of 80-mm. (3.2-in.) and 100-mm. (3.9-in.) thickness will be extensively applied."

. "Such plates with hardened surface of 80-mm. (3.2-in.) and 100-mm. (3.9-in.) thickness were tried in Meppen October 16th and 19th 1895."

The actual accounts of these trials, as published by Captain Castner and completed by the report of these trials in the *Marine-Rundschau* March, 1896, are given hereunder in form of tables and with photographs of the plates:

Krupp Plates.

10-*cm.* (3.9-*in*-) *Face Hardened Nickel-Steel Plate No.* 475.

Dimensions of the plate :—Thickness 10 cm. (3.9-in.), length 2.5 m. (8.2 ft.), width 1.5 m. 4.92 (feet).

Rounds I—V were fired against the plate and a backing, which consisted of 30 cm. (11.8-in.) oak, which both were fastened to a forged iron bulkhead with 40 mm. (1.57-in.) 2×20 mm. (2×0.79 in.) inner skin by means of 8.55-mm. (2.17-in.) bolts. Rounds VI and VII, were fired against the plate and a backing of 60 cm. (23.72 in.) oak which both were secured to the same bulkhead by means of 4 steel bolts. The bolts entered 50 mm. (1.97 in.) into the back of the plate. Rounds VIII and XIII were fired against the plate secured to the bulkhead without backing. Angle of impact 87°.

The author remarks on this trial (see tables at end of article):

"The ballistic test has indeed established the limit of the resistance of the plate against perforation, but not succeeded to ascertain its resistance against breaking, not even given a hint when such breaking could occur, since the plate showed no through crack after 13 projectiles were fired at it, although there are not less than 9 impacts only on the left side of the plate, three of which perforated the plate. This proves the extraordinary toughness of the plate, connected with equal hardness.

"The first round with the 8.8-cm. (3.5-in.) gun, although the point of impact was near the upper edge of the plate and thus favorable to the breaking effect, showed at once, beyond doubt, that this gun was not able to establish the power of resistance of this plate.

"Also the 10.5-cm. (4.1-in.) gun does not fulfill this task but at the limit of its capability. The limit of the power of resistance of the plate can be assumed between impact IV and XIII, if one does not attribute to the wood backing any influence on the power of resistance of the plate. But if one compares the effect of these two impacts, it is difficult to attribute the greater effect of impact XIII exclusively to the higher striking energy; there is no doubt that the absence of a backing has been of influence, but it is impossible to state to what degree.

"If we do not take into consideration the influence of the backing and determine the coefficient of quality of the plate according to the de Marre (or French) formula for soft Creusot plates, ('acier doux') $v = x\frac{a^{0.75}e^{0.7}}{p^{0.8}}$ where x, the coefficient of quality, is = 1530, we find that the coefficient of quality of this plate is 2391 for impact IV, and 2430 for impact XIII, the average being about 2410.

"But if we apply the same formula to the impacts from the 15-cm. (5.9 in.) gun, the result is quite different. The coefficient of quality for impact VII, which just perforated the plate, being only 2165.

"This proves that the coefficient of quality has only a relative importance, which depends on the caliber of the gun and stands in closest connection with it.

"A formula therefore is needed which gives correct data for all calibers. It cannot be denied that the quality of the shell is hereby of highest importance and that a formula can only give approximately correct results for plates, which break up the shells, if shells of the same material are used. The de Marre formula is only applicable as long as the shell remains intact or is but little changed during the impact. For the hardened Krupp plates, as far as their resistance against perforation was tested, the following formula, which was first laid down at the Krupp Works, gives approximately correct results:

$$p v^2 = 5800\, a E^2,$$

where v represents the striking energy in mts.
p the weight of the projectile in kg.,
a the diameter of the projectile in cm.,
E the thickness of the plate in cm.

"Whether this formula can also be applied to thick plates, is, according to the assertions of the Krupp Works, still unsettled, as such plates have not yet been perforated.

"According to this formula a plate of 100 mm. (3.9 in.) can be perforated by a 10.5-cm. (4.1-in.) shell of 16 kg. (35.3 lbs.) weight with a striking energy of 617 mts. (2034.3 feet-tons); the ballistic trial showed that 625 mt. (2050.6 feet tons) were necessary.

"The ballistic trial proved that the 100-mm. (3.9) plate has the same protective qualities by which the 146-mm. (5.7 in.) and the 300-mm. (11.8 in.) Krupp plates excelled. The 10.5-m. (4.1-in.) gun can perforate the armor only at the closest range and with the highest possible energy, but without being able to cause any effect in rear of the plate. This can only be done at close range by a 12-cm. (4.7-in.) gun, and at long range by the 15-cm. (5.9-in.) gun. The plate resisted 13 impacts and has borne a total striking energy of 5179.16 mt. (16713.2 feet-tons) without receiving a crack and without breaking."

[To be concluded.]

Krupp 10-cm. (3.9-in.) Face-Hardened Nickel-Steel Plate No. 475.

No. of Impact.	GUN.		Ratio of caliber to thickness of plate.	PROJECTILE.		Distance of plate from muzzle of gun.	VELOCITY.			Ratio b:c.
	Caliber.	Length.		Kind.	Weight.		a Muzzle velocity.	b Striking velocity.	c Velocity required to perforate an ordinary steel plate of equal thickness.	d
					kg. lbs.	m. f.	m. f.	m. f.s.	m. f.	
I	8.8 cm. (3.5 in.) Q. F.	L/24	0.88	*Krupp* A. P. steel shell L/2.6 Powder charge 0.87 kg. (1.92 lbs.) W. P. C/89	7.0 15.4	99 324.8	547 1794.6	528.4 1733.7	525.4 1723.8	1.01
II	10.5 cm. (4.1 in.) Siege.	L/35	1.05	" L/31 Powder charge 3.0 kg. (6.6 lbs.) P.P. C/68	16.0 35.3	"	401.1 1316.0	393.1 1289.8	396.8 1301.9	0.99
III	"	"	"	" Powder charge 1.90 kg. (4.2 lbs.) W. P. C/89	"	"	495.3 1625.0	484.8 1589.2	"	1.22
IV	"	"	"	" Powder charge 2.60 kg. (5.7 lbs.) W.P. C/89	"	"	633.1 2077.1	620.1 2037.5	"	1.56
V	15 cm. (5.9 in.)	L/30	1.5	" L/2.8 Powder charge 3.3 kg. (7.3 lbs.) W.P. C/89	40.0 88.2	121 397.0	415 1361.6	406.5 1333.7	326.4 1070.9	1.25
VI	12 cm. (4.7 in.) Siege.	"	1.2	" L/3.5 Powder charge 1.95 kg. (4.3 lbs.) W.P. C/89	26.0 57.3	99 324.8	509.5 1671.6	500.7 1642.7	344.0 1128.6	1.45
VII	15 cm. (5.9 in.)	"	1.5	" L/3.4 Powder charge 3.45 kg. (7.6 lbs.) W.P. C/89	51.0 112.4	121 397.0	415.8 1364.2	409.0 1341.9	289.1 948.5	1.41

Krupp 10-cm. (3.9-in.) Face-Hardened Nickel-Steel Plate No. 475.

Striking Energy.	Thickness of plate which the shell would have perforated according to French formula.		Penetration of point of projectile.	EFFECTS ON PROJECTILE.	EFFECTS ON PLATE.	No. of Impact.
	Ord'ry. Steel.	Iron.				
mt. ft.	cm. in.	cm. in.	cm. in.			
99.61 321.4	10.1 4.0	13.3 5.2	1.5 0.6	Broken up and fragments rebounded. Point of projectile welded into the plate, fell off at the sixth round.	Indentation 15 mm. (0.6 in.). The hard surface of the plate was broken off over an area of 80 mm. (3.1 in.) diameter and to a depth of 7 mm. (0.3 in.). Near the upper edge one concentric and two radial hair cracks. Back of plate: No effect.	I
126.0 406.6	10.0 3.9	13.0 5.1	0.5 0.2	Broken up and fragments rebounded.	Indentation 5 mm. (0.2 in.) deep and 100 mm. (3.9 in.) in diameter. Back of plate: No effect.	II
191.7 618.6	13.3 5.2	17.9 7.1	0.9 0.4	Broken up and fragments rebounded.	Indentation 9 mm. (0.4 in.) deep and 108 mm. (4.1 in.) in diameter with concentric hair cracks. Back of plate: The plate was bulged to the rear to a height of 5 mm (0.2 in.) and 125 mm. (4.9in.) in diameter.	III
313.6 1011.9	18.9 7.4	26.2 10.3	8.1 3.2 or 4.6 1.8	Broken up and fragments rebounded. Point of projectile welded into the plate, fell off at the sixth round.	Indentation 84mm. (3.2in.) deep. The surface of the plate was broken off about the point of impact over an area of 150 mm. (5.9 in.) in diameter. The plate was bulged to the rear to a height of 45 mm. (1.8in.) and 300 mm. (11.8 in.) in diameter.	IV
336.9 1087.2	13.7 5.9	18.4 7.2	2 0.8	Broken up and fragments rebounded.	Indentation 20mm. (0.8 in.) deep and 150 mm. (5.9 in.) in diameter. The hard surface flaked off. The plate was bulged to the rear to a height of 18 mm. (0.7 in.) and 200 mm. (7.9 in.) in diameter.	V
332.2 1062.0	17.1 6.7	23.4 9.2		Broken up, the point of projectile smashed, the cylindrical part split lengthwise into 4 pieces. Point of projectile welded into plate.	Indentation 180 mm. (7.1 in.) in diameter. Back of plate: Bulge of 35mm. (1.4 in.) height and 300 mm. (11.8 in.) in diameter, without cracks.	VI
434.8 1403.1	16.4 6.4	22.4 8.8	through.	Broken up, fragments of projectile in the shot hole.	Perforated. Diameter of shot hole: 155×156 mm. (5.1×6.1 in.). Fragments of the shell in the shot hole. The punched out section of the plate passed into the backing. The plate was bulged to the rear.	VII

ROUNDS VIII-XIII WERE FIRED AGAINST PLATE WITHOUT BACKING.

No. of impact.	GUN.		Ratio of caliber to thickness of plate.	PROJECTILE.		Distance of plate from muzzle of gun.	VELOCITY.			
	Caliber.	Length.		Kind.	Weight.		a Muzzle velocity.	b Striking velocity.	c Velocity required to perforate an ordinary steel plate of equal thickness.	d Ratio b:c.
VIII	10.5 cm. (4.1 in.) Siege.	L/35	1.05	*Krupp* A. P. steel shell L/3.1 Powder charge 2.60 kg. (5.7 lbs.) W. P. C/89	16.0 35.3	99 324.8	621.6 2039.4	608.6 1996.7	396.8 1301.9	1.52
IX	15 cm. (5.9 in.)	“	1.5	*Krupp* common shell with bursting charge L/3.7 Powder charge 11.5 kg. (25.4 lbs.) W. P. C/89	45.5 100.3	123 403.6	654.2 2146.4	642.4 2107.7	——	——
X	15 cm. (5.9 in.)	L/35	1.5	*Krupp* common shell with bursting charge L/3.7 Powder charge 11.5 kg. (25.4 lbs.) W. P. C/89	45.5 100.3	123 403.6	533.7 1751.0	523.6 1717.9	——	——
XI	“	“	“	“ 10.0 kg. (22.1 lbs.) W. P. C/89	“	“	585.2 1920.0	574.2 1883.9	——	——
XII	12 cm. (4.1 in.) siege.	“	1.05	*Krupp* A. P. steel shell L/3.1 Powder charge 2.88 kg. (6.4 lbs.) W. P. C/89	16.0 35.3	99 324.8	683.8 2243.5	669.9 2197.9	396.8 1301.9	1.69
XIII	“	“	“	“ Powder charge 2.68 kg. (5.9 lbs.) W. P. C/89	“	“	643.5 2111.3	630.1 2067.3	“	1.59

ROUNDS VIII–XIII WERE FIRED AGAINST PLATE WITHOUT BACKING.

Striking energy.	Thickness of plate which the shell would have perforated according to French formula.		Penetration of point of projectile.	EFFECTS ON PROJECTILE.	EFFECTS ON PLATE.	No. of impact.
	Ord'ry. steel.	Iron				
mt. ft.	cm. in.	cm. in.	cm. in.			
302.1 974.9	18.4 7.2	25.4 10.0	?	Broken up and fragments rebounded. Point of projectile welded into the plate, fell off at the tenth round.	Indentation 75 mm (3 in.) deep. The plate about the point of impact was broken off over an area of 150 mm (5.9 in.) in diameter. The plate was bulged to the rear to a height of 35 mm (1.4 in.) and 250 mm (9.8 in.) in diameter with horizontal cracks.	VIII
957.0 3088.2	—	—	thro'.	Exploded and broke up. The greater part of the fragments of the projectile perforated the plate, only a few pieces were found in front of the plate.	Plate perforated and a section punched out. Diametor of the shot hole, 300×280 mm (11.8×11.0 in.). Fragments of the punched out section passed into the backing. The back of the plate was broken out within a diameter of 530 mm (20.9 in.).	IX
635.8 2051.7	—	—	2.0 08	Exploded and broke up, fragments rebounded.	Impact struck the plate 250 mm (9.8 in.) from the upper edge. Several concentric cracks developed about the point of impact. The plate was bulged to the rear to a height of 15 mm. (5.9 in.) and 300 mm. (11.8 in.) in diameter.	X
764.6 2467.4	—	—	thro'.	Exploded and broke up, fragments rebounded.	Perforated and a section of a weight of 44 kg (97 lbs.) punched out. The back of the plate was broken out within a diameter of 350×280 mm (13×10 in.).	XI
366.0 1181.1	21.1 8.3	29.5 11.6	"	Broke up into small fragments. Point of projectile welded into the punched out piece of the plate.	Perforated and a section punched out.	XII
323.8 1044.9	19.4 7.6	26.8 10.5	"	Broke up into small fragments.	Perforated and a section punched out.	XIII

c. Powder and Explosives.

High Explosives and Smokeless Powders.*

By Hudson Maxim.

I first began the investigation of the subject of high explosives and smokeless powders in England, in 1889. Since that time I have built two powder mills in America, one for the manufacture of high explosives, the other for smokeless powders for ordnance. In connection with my other work on these lines, I conducted a large number of experiments for the Pneumatic Torpedo and Construction Company, of New York, formerly known as the Zalinski Dynamite Gun Company, looking to the production of a smokeless torpedo powder, that is, a powder for the purpose of throwing high explosives or aërial torpedoes from ordnance.

Owing to the shortness of range of the pneumatic guns, and to the expense, cumbersomeness, and vulnerability of the plant necessary to operate them, it was determined, if possible, to substitute powder for compressed air. How well we have succeeded with smokeless powder, and the special advantages smokeless powder has for the purpose, is one of the things which I shall try to explain this evening.

The value of systems of offence and defence in war depends upon the degree of their efficiency as compared with their expense. For coast defence that weapon is best which, at a given expense, will cover entrances to harbors over the greatest range, and be itself least exposed to the fire of an enemy. On shipboard that weapon is best which, at a given cost, weight and exposure to the fire of the enemy, will be most efficient in the destruction of other vessels and of coast fortifications. All these requisites, I believe, are embodied in the system of throwing high explosives from ordnace with gunpowder, which I present to you this evening. The nearest approach to it yet developed is the system of throwing high explosives by means of compressed air. But the shortness of range of pneumatic guns, the difficulty and expense of protecting them, and the enormous plant of engines, boilers, and air compressors necessary, are strong objections against their use for coast defence, while their cumbersomeness and vulnerability, together with the above objections, render their employment on shipboard entirely out of the question.

With the 15-in. pneumatic guns now in use, 500 lbs. of high explosive may be thrown a distance of about one mile; 200 lbs. about two miles. This is the maximum range. Hence a man of-war could lie just beyond the range of these guns and destroy the entire outfit without being exposed in turn to the fire of the pneumatic tubes. It is obvious, therefore, that a practical system of throwing aërial torpedoes must have a range substantially equal to that of high power guns opposed to it, and the quantity of high explosives thrown must be sufficient to effect upon the target greater destruction than can be effected by ordinary shell thrown from high power guns.

The next nearest approach to the system of throwing high explosives, which I present is to be found in that of mortars employed in coast defence at the present time. These mortars, which are generally arranged in batteries of four, are not usually trained upon the target to be destroyed but upon an area of the channel through which the target must pass in entering the harbor. Considering the difficulty of securing great accuracy of fire with mortars, and the comparatively small amount of work the shell will do even when striking, in order to safely cover any considerable area and bring to bear upon an approaching fleet sufficient energy to account for much, it is necessary to employ a large number of mortars, all of which have to be protected from the fire of the enemy.

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* Paper read before the Society of Arts, May, 1896.

The present United States mortars are of 12-inch caliber, and are 12 calibers long. The travel of the shot through the bore is about 9 ft. The cost of the mortars is about $18,000 to $20,000 apiece, and it is safe to estimate that the cost of protecting coast guns or mortars is about equal to that of the weapons themselves. The weight of shell used for piercing the decks of a man-of-war is about 1,000 lbs., and will carry from 75 lbs. to 100 lbs. of explosives. Only 10% of the weight thrown, therefore, is explosive. In order to do any considerable damage, the shell, in falling, must strike the deck of a man-of-war point down: its efficiency depending upon its penetrating power to pass through the ship's deck and down through her bottom, upon the destructive effects of its explosion within her compartments, or between decks, and upon the large pieces of shell thrown as missiles. A mortar shell striking in the water beside a ship does no particular damage, unless by chance it strikes very close to her sides, and explodes exactly at the right point and depth. Such a result, however, is purely accidental, and is not to be calculated upon.

The chief thing to be considered in an aerial torpedo or high explosive shell, is the quantity of high explosive it will carry, and the character of the explosive should be such as to develop the greatest amount of energy for the space it occupies.

In order to insure the disruption of the unprotected side of a man-of-war below the water-line, it is necessary to apply an explosive energy of at least 6,500 lbs. to the square inch. This represents the crushing energy transmitted through 16 ft. of water by the explosion of 100 lbs. of gun-cotton, or the energy transmitted through about 20 ft. of water by the explosion of 100 lbs. of nitro-gelatin. Now, as the crushing energy exerted by an explosive through water against the wall of a ship decreases as the square of the distance from the vessel, it requires the explosion of at least 500 lbs. of nitro-gelatin or an equivalent high explosive within a distance of 50 ft. to insure the destruction of a man-of-war, and such a quantity exploding within such a distance may be counted upon as practically certain to produce the desired result.

It should be borne in mind that these figures represent distances through which destruction may, with certainty, be depended upon. The terrible force of concussion of 500 lbs. of high explosive transmitted through water will open seams in the hull of a man-of-war, even from a distance of 150 ft., and cause dangerous leaks. Some of us who have returned from a day's outing with a string of fish sufficiently large to support our reputation as fishermen have had opportunity to witness the deadly efficiency of a dynamite cartridge exploded under water.

The smokeless torpedo powder is made to burn with a constantly increasing combustion surface, thereby securing a corresponding increased evolution of gases. Through the use of this powder, which gives a low initial pressure, and keeps that pressure up throughout the bore of the gun, comparatively sensitive explosives may be thrown with perfect safety at very long range. Shells or containers with thin walls may be used, because the projectile is not started with sufficient velocity to require very strong and thick walls to stand the set-back of the explosive they contain. On striking the target such a shell does not depend upon its own walls to furnish missiles, for the force of the explosion will be such that the wood or ironwork about the crater of its action will be utilized as missiles, and the effective zone of danger and destruction from the terrible concussions of a charge of (say) 500 lbs. of nitro-gelatine will be incomparably greater and more fatal than the danger zone due to the explosion of a thick-walled mortar shell containing a small charge, even when due account is taken for the efficiency of the latter's missiles.

The gun may be made of any desired caliber. It consists of a single forged steel tube, and should have a thickness sufficient only to give it enough rigidity and weight to modify the force of its recoil, and enable this to be more easily controlled. To withstand simply the pressure required to give the necessary velocities, a gun of even 20-inch caliber would require a thickness of only about 2 inches.

FIG. 1.

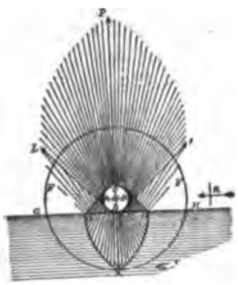


ILLUSTRATION OF ACTION OF AN AERIAL TORPEDO OVER OR UPON A SHIP'S DECK.

FIG. 2.

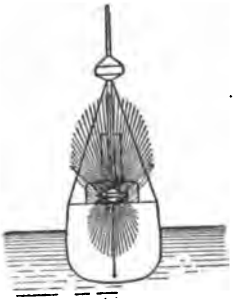


ILLUSTRATION OF ACTION OF EXPLOSION ADJACENT TO A FIRM RESISTING BODY, AS A SHIP'S DECK OR THE EARTH'S SURFACE.

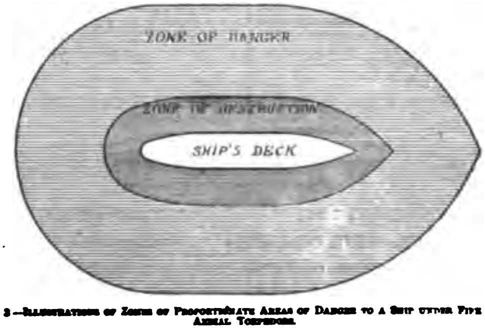


FIG. 3.—ILLUSTRATIONS OF ZONES OF PROPORTIONATE AREAS OF DANGER TO A SHIP UNDER FIRE FROM AERIAL TORPEDOES.

A 13-inch gun of this type, using a pressure of 5,000 to 7,000 lbs. to the square inch, will throw 250 lbs. of explosive gelatine a distance of about five miles; 450 lbs. over two miles. A 20-inch gun of this type, using similar pressures, and having a length of travel for the projectile of 25 feet, will throw 200 lbs. of explosives more than ten miles; 500 lbs. about seven miles; and 1,000 lbs. over five miles.

A large shell is made for a 4-inch gun. The shell is fitted with a fuse adapted to explode when it shall have penetrated to any desired distance or depth below the surface of the water or within the deck of a ship. So uniform are the pressures and velocities attainable with this torpedo powder, that it is only a question of training the gun upon the target located by the range-finder anywhere within a circle of ten miles, to ensure the complete destruction of any man-of-war which should dare to come within range. It is obvious that the gun may be so erected as to be fired at any desired angle of elevation or depression.

The building, erection, and protection of a gun of this type of sufficient caliber to guard any port against bombardment would cost much less than any other means of protection, and it would be far more efficient. In fact, the cheapness of the gun and mounting is a very strong argument in its favor.

It is obvious that this system of throwing high explosives is equally efficacious on shipboard against coast fortifications, and for the destruction of other vessels at sea.

It is not necessary that a high explosive shell should fall downward upon a ship's deck. Practically the same result is had if the shell is fired directly across the ship's deck and exploded upon striking any of her superstructure.

Fig. 1 will illustrate the action of a dynamite explosion adjacent to a firm, resisting body, such as the earth's surface or the deck of a ship, There is a well-known theory that the action of dynamite is downward. It is often noted that buildings adjacent to a dynamite explosion have their windows blown out from within, and in the direction of the explosion. In this figure I have endeavored to illustrate the action of such an explosion. E represents an explosive body. If it were suspended in space, or within a body of uniform resistance, its action would be uniformly even in all directions, as inscribed by the circle F; but, placed adjacent to the earth or other firm resisting body, as G H, its action is to throw the entire mass of explosive or weight of its gases upward into the air, and the greatest display of action above the earth is in the direction of the line, P. Now, to raise a weight of 500 lbs., whether the body be solid or gaseous, at the velocity of gases of explosion, requires an enormous energy, without taking into account the resistance of the air. The body of explosive, E, may be likened to a ball of perfect elasticity, caused to rebound from the earth, exerting downward a pressure equal to the force which raises it. Hence, a force is exerted downward, to form the crater in the line, P, equal to the force exerted upward, and which is sufficient to raise a weight of 500 lbs. at a velocity of gases of explosion. The action of the explosion being chiefly downward and upward, a partial vacuum may be formed, and an inflow of the surrounding air occur in the direction of the arrow, R.

Fig. 2 illustrates the effect of the explosion of an aerial torpedo in its transit across the deck of a man-of-war. The explosive, being tamped by its own weight, and by the resistance of the surrounding air, will re-act upon the ship's deck with a destructive effect similar to that of a torpedo exploded under water adjacent to a ship's side.

Fig. 3 illustrates the danger zone of a ship under fire from one of these guns throwing a charge of 500 lbs. of high explosive, such as nitro-gelatine. As this amount is sufficient to sink any man-of-war afloat when striking within fifty feet of her, and as it is necessary to hit the vessel itself with the ordinary mortar shell in order to injure her, the danger zone, in favor of this gun throwing this charge, is more than quadruple that of the mortar, even though the mortar could be counted upon as certain to sink a ship upon hitting her, which is far from true. Whereas, with 500 lbs. of high explosive, to hit is to destroy. A 20-inch gun of this type will throw 1,000 lbs. of high explosive at a range equal to any coast mortar, and with far greater accuracy, thus still further increasing materially the zone of destruction. Furthermore, as the sea area within the range of these guns is more than three times that within the range of the mortar, and as the mortar cannot be trained and directed with anything like the same readiness and degree of accuracy, it appears to me that the efficiency of the two weapons as a means of coast defence is not to be compared.

—*Industries and Iron*, May 15, 1896.

(To be continued.)

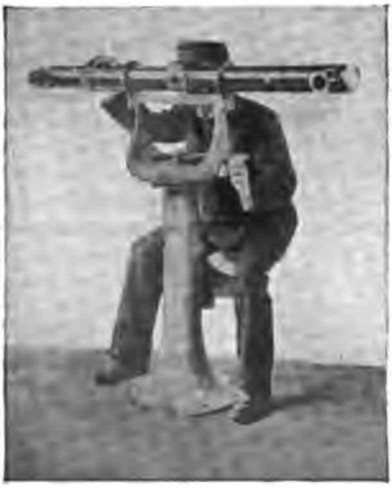
d. Torpedoes.

* * * * * *

e. Range and Position Finders.

The Barr and Stroud Fortress Range-Finder.

We illustrate a fortress range-finder constructed by Messrs. Barr and Stroud, of 250, Byresroad, Glasgow, W., which is of the same type as the naval instrument described in our issues of February 14 and 21 last. As there explained, the finder consists essentially of two mirrors fixed at each end of a horizontal tube standing at right angles to the line of sight. The image from each mirror is reflected to a single telescope, in the field of which one is seen super-imposed on the other. Exact coincidence of the two is secured by shifting an adjustable prism, the position of which is a measure of the range of the object. In the present instrument the stand has been arranged with a special view to convenience and ease of operation in forts and other positions on land. The details of the instrument are shown in Figs. 1 and 2, whilst its general appearance will be understood by a reference to Fig. 3. From these views it will be apparent that the stand consists of a cast-iron pedestal carrying at its upper end a steel forging, and at some distance above the base a gun-metal collar. The steel forging forms the lower member of a ball bearing, the upper member of which consists of a steel ring carried by a tubular sleeve encircling the upper part of the pedestal. The sleeve is guided at its lower extremity by a gun-metal bush working upon the ring carried by the pedestal. The sleeve is flanged at its upper end, and to the flange a circular dish-shaped casting is bolted. This casting forms a protection for a graduated circle 18 in. in diameter, and also affords support to a worm which gears with a wormwheel capable of being clamped—through the medium of the graduated disc—to the steel spindle carried on the top of the pedestal. The dish shaped casting is prolonged upwards in the form of two brackets or cheeks connected at the top by a crossbar, and carrying forks identical with those carried by the swinging frame of the naval range-finder. In these forks the telescope portion of the range-finder rests, and in them it is capable of being rotated in altitude by a worm gear carried on the cross-bar.



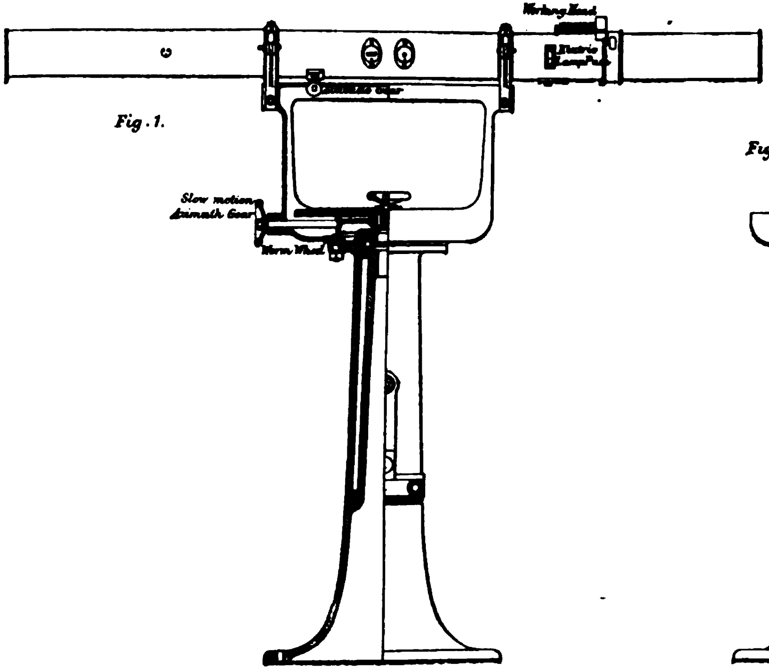

Working Head
Electric Lamp
Gear
Slow motion Azimuth Gear
Worm Wheel

Fig. 1.

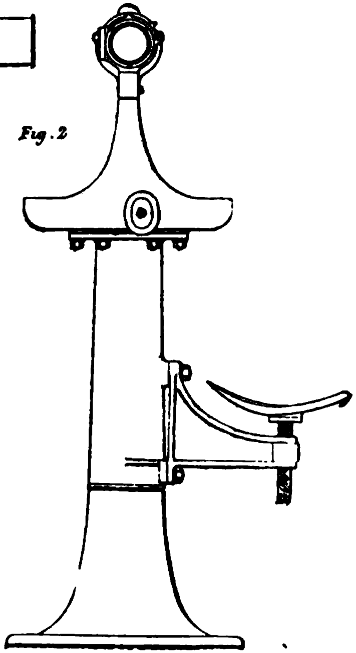


Fig. 2

The boss of the graduated disc is bored to fit the steel spindle carried by the pedestal, and has a groove or keyway fitted to a feather projecting from the spindle. The disc is therefor fixed azimuthally when the pedestal is bolted down to the foundation upon which it stands. The spindle is free to rotate in the pedestal casting for adjustment of the graduations of the graduated disc into conformity with the azimuth scales of the guns, and when this adjustment has been made, the spindle will be fixed to the pedestal. The outer surface of the boss of the graduated disc is made conical, and fits into a conical recess in the wormwheel, into which it may be clamped by a screw provided with a handwheel. A friction clutch is thus constituted, which can be tightened or slackened at will. When the clutch is loose, the wormwheel is free to rotate about the pedestal, and thus the pedestal may be freely and quickly turned in azimuth. When the clutch is clamped, a slow motion can be communicated to the instrument by means of the azimuth worm gear, which is, for that purpose, provided with a handwheel conveniently placed for being operated by the range-taker's left hand. The section (Fig. 1) shows the wormshaft as if it passed radially inwards from the left-hand side of the bracket casting, but it really passes in at about 45°, which angle carries it to the far side of the wormwheel, and also presents the handwheel in a very convenient attitude to the operator. The rotating sleeve carries a bracket from which a seat—adjustable in height—is supported. The operator, sitting on the seat, has his feet upon the base of pedestal, and can then turn himself and the instrument freely in azimuth if the clutch is loose, but when the clutch is tightened, the instrument and operator are moved together by the rotation of the azimuth worm gear. The clutch, however, may be only partially tightened, so that the operator can move the instrument rapidly round in azimuth and also adjust it more finely and move it slowly by aid of the worm gear to follow the motions of the enemy. The object of providing the range-taker with a seat instead of designing the range-finder for use from a standing posture, is twofold: 1. The attitude is found a more comfortable one for the range-taker, especially when long on duty, and conduces to more accurate work. 2. The height of the instrument is reduced thereby, and therefore the protection—if any is provided—may be more conveniently and effectively arranged.

The index of the azimuth circle is fixed to the far side of the dish-shaped casting, so that the azimuth can be read by a separate observer, and when necessary for identification of the object, communicated by him to the gunners without disturbing the range-taker in his operations. This will be very convenient for such purposes as locating the site of submarine mines as indicated by the boat from which the mine is being laid, as well as for locating an enemy's ship for gun or mine firing.

The instrument, as is well known, is very rapid in its operation. The distance of an object can be determined in from 8 to 12 seconds from the time that the range-taker reaches the instrument, *i. e.*, the operations, turning the instrument in azimuth, finding the object in the telescope, effecting coincidence of the images and reading the scale, can all be effected in, say, 10 seconds, and the range-taker can then in 8 to 10 seconds more find the range of a second object, and so on. The naval range-finder is found in many cases not to require the slightest adjustment during many months of use at sea, though exposed to all weathers and constantly being placed on its stand and

Tests of Barr and Stroud's Range-Finders.

Instrument Number.	Graduated in	Range of a House Distant 326 yards (298 Meters).	Equivalent Error at 3000 Yards.*	Range of a Chimney Distant 1975. Yards (1805 Meters).	Equivalent Error at 3000 Yards.*	Range of a Steeple Distant 5950 Yards (5440 Meters).	Equivalent Error at 3000 Yards.*
		mean	mean	mean	mean	mean	mean
68	yards	325.88 yds.	—.34 pc.	1974 yds.	—.08 pc.	5950 yds.	.00 pc.
69	"	325.68 "	—.69 "	1970 "	—.38 "	5990 "	+.34 "
70	"	326.16 "	+.45 "	1982 "	+.54 "	5980 "	+.25 "
71	"	326.08 "	+.23 "	1975 "	.00 "	5980 "	+.25 "
81	meters.	298.22 ms.	+.75 "	1803 ms.	—.18 "	5640 ms.	.20 "

* The accuracy asked for by the British Admiralty in their advertisement for range-finders for the Navy was 3 per cent. at 3000 yards.

removed from it again to its box. In fortress work, when the telescope portion need not be removed from its stand, there should be no danger of accidents which might cause derangement, and the instrument is so constructed that, barring actual damage, it does not vary in its indications with changes of temperature or other causes. It can, however, be tested by an observation on the moon, on a star, or upon any object at a known distance, and if found wrong, it can be very easily put into correct adjustment by means of the adjusting heads provided for the purpose. These heads are protected by a cover, so as not to be liable to accidental movement. The accuracy of the finder is well shown by the figures in the previous column, giving the mean errors observed in five different instruments, the readings being taken on shore.

—*Engineering*, December 4, 1896.

FORTIFICATIONS.

Field fortifications cannot preserve their former profiles in view of the penetration of bullets of the new rifles in freshly piled earth. It becomes necessary, above all to rely on the natural ground itself, as offering more resistance, and no *hold*, so to speak, for the bullets.

An appendix to the regulation on field fortification prescribes certain modifications to be made, in this sense, in the shelter trench. Already the height of the parapet had been reduced from 0.6 m. to 0.3 m. in every case where, with this slight relief, sufficient field of view was maintained, and where time was had to deepen the trench. Now it is proposed to do away with the parapet as much as possible: a width of 1 m. will be given to the bottom of the trench, the depth will be made 1.4 m., and in the natural soil a berm will be made to support the elbows and to put cartridges on. The earth dug out, with which ordinarily the parapet is constructed, will be carried away or thrown to some distance.

Thus there will be obtained shelter trenches that are strong and almost invisible, the effect of which will be, they will no longer attract the fire of artillery. Measures will be taken, moreover, to mask them from the view of the enemy and to prevent them from being outlined along crests or distinguished from the ground itself. This can be accomplished by suitably arranging branches of trees and by the use of turf. The men will always remove their helmets.

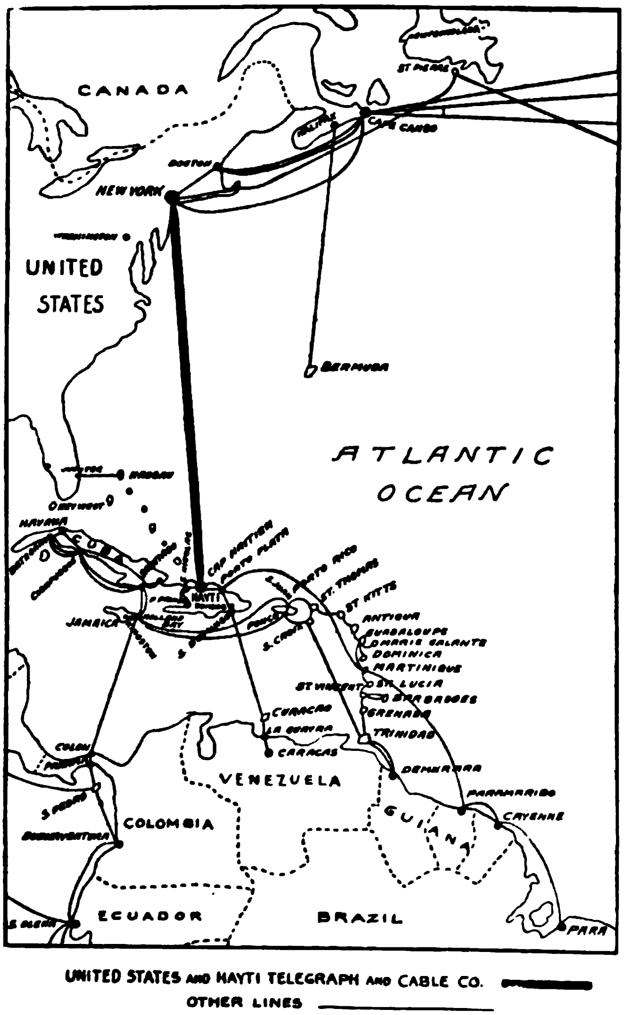
We call attention to these regulations. They cannot always be completely carried out; sometimes it will be difficult to do away with the earth dug out, and also time may be wanting to give the trenches the desired depth. It is none the less true that they will be highly advantageous whenever they can be applied.

—*Revue du Cercle Militaire*, June 27, 1896.

MILITARY GEOGRAPHY.

The new Cable to Hayti.

The submarine cable between New York City and Hayti was opened to the



THE NEW YORK–HAYTI CABLE.

public at midnight, December 1, for the transmission of messages to and from the West Indies. The cable approaches New York by the way of Coney Island and Brooklyn. The main office of the company is at 1 Broad street, where the Commercial Cable Company has its office, and messages will also be accepted at all Postal Telegraph Company offices throughout the country. Interest attaches to the enterprise from the fact that the Attorney General of the United States applied recently for an injunction to prohibit the company completing its plans, alleging that it was a cloak for a foreign company. The United States and Hayti Telegraph and Cable Company replied, proving itself a bona fide American company, and declaring that its object was to establish a competing service and to reduce rates.

The course of the new cable is shown in the accompanying map, the original of which has kindly been made for us by Vice-President George Clapperton, of the United States and Hayti Cable Company. The various connections are indicated. It will be noted that Hayti still has to reach Jamaica by way of Cuba. The new cable is about 1,500 miles long and has a resistance of 5 ohms per knot. The rate from New York City to Mole St. Nicholas, is $1.50 or a reduction of 35 cents per word, and the same to Port au Prince, or a reduction of 60 cents. Venezuela is reached for $1.70 per word, or a reduction of 70 cents a word.

—*The Electrical Engineer*, December 16, 1899.

The Guatemala Northern Railway.

One of the most important railway projects now being carried out in Central America is the Guatemala Northern Railway, which extends inland from the port of Puerto Barrios, on the Atlantic coast (Gulf of Honduras), following the valley of the Motagua River, and being practically parallel with the Honduras frontier. This line was commenced by the government in 1883, when General Rufino Barrios was President. After his death, in 1884, work was suspended, with only three miles of track laid. The enterprise remained dormant until 1893, when President Reyna Barrios entered into a contract with Mr. Silvanus Miller M. Am. Soc. C. E., for the completion of the first 20 miles. Since then, by several contracts with Mr. Miller, the construction has been steadily continued, and the line is now open for traffic from Puerto Barrios to Gualan, 80 miles. In July it will be opened to Zacapa, 101 miles, and by October it is expected to be in operation to "El Rancho," 134 miles from Puerto Barrios. The road is intended to form a part of a transcontinental route, and will probably be completed to Guatemala City, about 200 miles, in 1898, connecting there with the Guatemala Central Railway, which is now in operation from that city to the port of San Jose, on the Pacific coast, a distance of 75 miles.

The line has a gage of 3 feet. The track has 40-lb. rails for the first 18 miles, and 56-lb. rails for the rest of the distance, while the 40-lb. will soon be replaced with 56-lb. rails. There are turntables at Puerto Barrios, Los Amates, Gualan and Zacapa; also well equipped shops at Gualan, and a small shop at Puerto Barrios. A fine wharf has been built at this latter place, where ships of 5,000 tons have discharged their cargoes. The equipment includes 8 Baldwin locomotives, 1 parlor car, 13 passenger cars (including baggage cars), 30 box cars, 115 flat cars and 2 wrecking cars.

The Guatemala Central Railway is 75 miles long, with maximum grades of 3% and minimum curves of 15°. The track has 54-lb. rails, laid on wooden ties, 24 ins. c. to c., in stone and blue gravel ballast.

—*Engineering News*, July 2, 1896.

WARSHIPS AND TORPEDO BOATS.

Torpedo Boat Destroyer "Capitan Orella."

The *Capitan Orella* is one of four similar vessels which have been ordered by the Chilian government, and is similar in design to the 10 vessels of the *Quail* class which Messrs. Laird have now in hand for our own navy. The vessels are 213 feet in length, 21 feet 6 inches wide, and 12 feet 9 inches deep. The machinery is, in general design, similar to that placed in vessels of this class, with which our readers are familiar. Water-tube boilers are, of course, used, this firm having adopted a modification of the Normand type. The official speed trial was made on the Clyde on the 30th of last month, and was entirely satisfactory. The guaranteed speed was 30 knots; but, without undue forcing, the engines running at a speed of 360 revolutions, a speed of 30.25 knots was obtained for the three hours' trial. The mean speed during the six runs on the mile was somewhat below this, being 30.18 knots. The horse-power was 6200, certainly a most surprising performance, even in the present day, when the total displacement is taken into account.

—*Engineering*, October 16, 1896.

H. M. S. First-Class Cruiser Powerful.

As the heavy ironclads which had been added to the navy just previous to the submission of the Naval Program of 1889 to Parliament were a class of ships quite incapable of defending our commerce of the country or of saving us from depredations at sea, it was decided after much discussion that what was wanted for the purpose was swift and powerful vessels capable of keeping the sea, of convoying a fleet of merchant ships, and of making rapid passages to distant parts without recoaling. Of such vessels, the program referred to proposed to build several, to be henceforth known as "protected cruisers." Many such vessels, ranging from 3000 to 8000 tons displacement, have already been constructed, and added to our navy, all of them built from the designs of Sir W. H. White, Chief Naval Constructor. On the completion of the vessels of this type ordered in 1889, it was considered advisable by the naval administration of the country, in view of any possible naval conflict with a foreign power, that more ships of this class should be built, but of much greater power and speed and coal endurance.

In the Navy Estimates of 1893-94 provision was made for the construction of two cruisers—the *Powerful* and the *Terrible*—which were to be the largest, swiftest, and most powerful vessels of the class ever built. The designs of these were at once put in hand, and tenders invited for their construction. Of those submitted, that of the Naval Construction and Armaments Company, Barrow-in-Furness, for the *Powerful*, was accepted; the building of the sister ship being entrusted to Messrs. J. and G. Thomson, of Clyde Bank, Glasgow. As the *Powerful* is now undergoing her machinery trials, and in all probability will be the first of the two completed, a description of her, with that of her propelling machinery, equipment, etc., may be given here. It will equally apply to both vessels.

As some departure has been made in her construction from that of previous vessels of the same class, she practically becomes a new type of cruiser, in that all side protection is dispened with, and in its place is substituted an armored deck, which offers powerful resistance to the penetration of projectiles; the resisting power of the usually fitted belt being added to the normal strength of the deck.

The *Powerful*, whose construction was commenced early in 1894, is of the following principal dimensions: Length between perpendiculars, 500 ft.; over all, 538 ft. She has a beam of 71 ft., and at her load draught of 27 ft. she displaced about 14,250 tons. She is composed entirely of steel, with the exception of her stem, stern, and rudder frames, which are of phosphor bronze, these latter being heavy castings, totalling some 50 tons in weight.

In the hull proper, great pains have been taken by a skilful disposition of the material to obtain extreme lightness, combined with great strength and rigidity. The vessel has six decks. viz., platform, orlop, protective, main, and upper and boat decks. The protective or armored deck runs the whole length of the ship, and is of great strength, being 4 inches at its thickest part, tapering to 3 inches at the ends, and is made of three thicknesses of steel plate. This deck dips at the ship's sides 7 feet below the load water-line, and rises 3 feet 6 inches above it on the middle line, thus giving 10 feet 6 inches of camber, and enabling the tops of the engine cylinders to come under it without resorting to armored engine hatch coamings, as in some late cruisers. By adopting this design of protective deck a good depth and breadth of coal armor is provided on both sides of the ship. The vessel has no external keel, and is structurally built on the bracketed system. Being intended to keep the sea, the hull is sheathed with teak and coppered. Heavy bilge keels, 224 feet long, are fitted on each side, and are metal sheathed. The rudder, which is on the balanced principle, is some 15 tons in weight and of large area.

The ship internally is divided into compartments by numerous transverse water-tight bulkheads; 240 feet of the middle length of the vessel is occupied by the machinery space, which is divided up into ten compartments, two of which are devoted to the propelling engines, and the remainder to the boilers; a longitudinal middle line bulkhead running through the whole of this length.

Between the armored protective deck and the one above it—the main deck—the whole of the 240 feet of length is divided up by numerous water-tight bulkheads into coal bunkers, which, when filled, form a coal protection for the whole of the machinery space, the horizontal thickness of coal being between 9 feet and 10 feet. As we intend in subsequent issues to give further constructive details of the vessel, and of her propelling and auxiliary machinery, we shall now briefly describe the main engines, and also note the kind of boilers with which the vessel is fitted, and which we illustrate in detail on page 338.

The propelling machinery of the ship consists of two independent sets of inverted four-cylinder triple-expansion engines, driving four cranks, designed to develope about 25,000 indicated horse-power when running at about 110 revolutions per minute, with 210 lb. steam pressure at the engines. The sequence of the cylinders is, one high-pressure, one intermediate-pressure, and two low-pressure, as shown in our engraving. Each engine has two air pumps, one worked off the high-pressure cylinder crosshead and the others from the forward low-pressure crosshead, and a separate main condenser.

The boilers supplying the engines with steam, which are 48 in number, are of the Belleville water-tube type, and are located in eight separate water-tight compartments or boiler rooms, which are all forward of the engines.

H.M.S. Cruiser *Powerful* is at present undergoing an exhaustive series of trials in the English channel.

So far the Belleville boilers have given every satisfaction, the pressure being uniformly maintained, and no trouble whatever was experienced with feed. The stoking seemed easy for the men, who have, of course, benefitted by their previous experience in the sister cruiser *Terrible*. The conditions of weather on Monday and Tuesday were throughout most favorable. A few runs were made over the measured mile in Stokes Bay, the engines indicating about 5200 horse-power and the ship making 15.3 knots with the tide and against the wind, and with these conditions reversed the speed was lessened by two knots.

—*The Engineer*, October 2, 1896.

GENERAL MILITARY MATTERS.

Range Tables.

The range tables of the 8-inch breech-loading rifle (steel), the 10-inch breech-loading rifle (steel) and the 12-inch breech-loading mortar for projectiles weighing 800 pounds, prepared by Captain James M. Ingalls, 1st Artillery (first published in the *Journal U.S. Artillery* for October, 1893, and March-April and May-June, 1896), having been proved to be accurate by actual firings, are published in Artillery Memoranda, No. 1, Headquarters of the Army, Washington, November 5, 1896, and consequently are now officially adopted.

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BOOK NOTICES.

The Elementary Principles of Mechanics, by A. Jay DuBois, C. E., Ph. D. Professor of Civil Engineering in the Sheffield Scientific School of Yale University. Author of "Elements of Graphical Statics," "The Strains in Framed Structurs," etc. 3 vols. 8vo. Published by John Wiley & Sons. New York, 1894-5. $10.00.

The fundamental principles of mechanics are now so well established from the numerous facts that have been gathered from observation and experiment that it may be said to be an exact science. These facts have all been duly marshalled under their appropriate heads and have been shown to be the direct consequences of a single general law that governs all physical phenomena. This law, known as that of the "Conservation of Mass and Energy" when formulated by the symbols of mathematics into an equation and treated by the methods of mathematical analysis furnishes a substantial basis for a comprehensive study of theoretical mechanics. But unfortunately the ordinary student is not at present sufficiently well equipped with the mathematical weapons to enable him to attack with success, this great and comprehensive law, and he is obliged to have recourse to the elementary methods of algebra and geometry for a fragmentary and imperfect knowledge of mechanics. As a consequence many text-books have been written for the ordinary college course of which there are relatively but a few that have a distinct educational value. To the latter class Professor DuBois' "Elementary Principles of Mechanics" undoubtedly belongs. He has endeavored however to meet the requirements of two classes of students of different mathematical attainments, by combining an abridged and an advanced course together; using algebraic and geometric demonstrations for the former course and extending it for the latter by interpolating other discussions in which the calculus lends its efficient aid. We do not think this combination a happy one for the reason that it has resulted in a very voluminous treatise much too extended to be thoroughly mastered in the time usually devoted to this subject in any college course. In the preface of the last volume, Professor DuBois in speaking of the method which he prefers for teaching mechanics says, "The other way is that here pursued, of giving the student a work sufficient for his needs, written with direct reference to his needs and development from beginning to end, while at the same time it allows of all desirable curtailment in the introductory work. It is so presented that the subject may be taken up earlier than is customary and made to illustrate and help in the other mathematical studies of the course." * * * "The present work is an attempt to take the beginner and leave him with a work which shall be of permanent value to him during and after his entire course."

The plan which he adopts in teaching the work is "to first go over all three volumes omitting everything not absolutely essential, taking thus only selected portions of the large print. When the student thus has a connected and intelligent grasp of the whole subject the remaining time is employed in picking up those omitted portions which are of the most importance."

The first impression one gets from an examination of this work is that it is unduly voluminous for the ground it covers, for the three volumes contain

1159 pages. But this includes more than a thousand problems and examples, many of which are carefully and minutely worked out to serve as a type of similar ones that may arise in actual practice, and the value of these to the student are, as the author says, very great. The first volume deals with kinematics, or the science of pure motion. In the method of treatment, general arrangement and some of the examples selected the author has followed quite closely the text-book of Professor J. G. MacGregor of Dalhousie College, Halifax, entitled "Kinematics and Dynamics" published by MacMillan & Co., in 1887. The distinction between speed and velocity, proposed by Professor Tait, is elaborated in Professor Macgregor's work and Professor DuBois, apparently without the usual acknowledgement, has adopted the latter's treatment with some minor changes of arrangement in the work under review. A greater amount of space is thus devoted to speed, acceleration of speed, displacements, velocity, acceleration of velocity, and moments than seems to be requisite, but the author has doubtless considered it most important to dwell upon these fundamental ideas. The use of the differential coefficient would manifestly have allowed much abbreviation. The principle of the parallelogram, by means of which all vector magnitudes may be compounded and resolved, once established, becomes applicable without repeated proof in every case. This being true of moments it is objectionable to say (page 61) that the moment of a displacement is "twice the area swept through by the radius vector" thus depriving it of its right-line characteristic without any compensating advantage. A fair criticism of this volume is that a great portion of it deals with problems of motion where the cause of the motion is taken into consideration and therefore properly belongs to kinetics. As it is, frequent back references in Volume III. occur which mars the continuity of the text.

The four introductory chapters of Volume II. deal with the elementary definitions of mass, force, density, center of mass, the composition and resolution of forces, and attractions; they contain besides many excellent examples to illustrate these fundamental ideas. Nine chapters are devoted to statics proper of which four treat of concurring and non-concurring forces, one on the equilibrium of strings, a concise and admirable chapter on graphical statics, one on virtual work and the remaining two on constrained equilibrium. These are followed by four excellent chapters upon the application of statics to retaining walls, dams, and earth slopes; strength and elasticity of materials; theory of flexure; and the continuous girder. These latter chapters are very valuable additions especially for the students of engineering, as they contain many applications worked out with great minuteness. Some modification of the language used in defining virtual displacement and virtual work, pages 159-160, would seem to be necessary for a true conception of these terms. It is hardly necessary to say that "an indefinitely small displacement of a point which does not actually take place" is nonsense.

Volume III. treating of kinetics, consists of two parts; the first comprising ten chapters treats of kinetics in general and the second, of four chapters, discusses that of a rigid body. A knowledge of the calculus is required to read a considerable portion of this volume, which therefore belongs to the advanced course.

In the discussion (page 18) upon the "deflecting force on the earth" there is a manifest error in supposing that there can be a central deflecting force along the radius *PC*, for the path of the particle is on the circle of latitude and the deflecting force is in the direction *PB*.

Professor DuBois is to be congratulated upon the clearness of his definitions and demonstrations throughout; upon the valuable store of illustrative examples which he has gathered together and the thoroughness with which he has elaborated the solution of many problems that lend themselves to the elucidation of principles. As a book of reference it will prove of great value to many teachers and to students who afterwards engage in engineering practice. P. S. M.

What is Electricity? The International Science Series, Volume LXXV., by John Trowbridge, Harvard University. D. Appleton & Company, New York. Price $1.50.

To the question, What is science? it may be said that science in its present and best sense has come to mean systematic organized knowledge respecting *any subject*. It does not reside in the subject matter but in the *nature of the knowledge*,—knowledge is the material of science; it becomes science only when organized and systematically co-ordinated.

In the opening chapter of Professor Trowbridge's book, which is the latest addition to the International Scientific Series, this fact is pointed out and the belief expressed that all subjects are soon destined to be studied after the patient systematic methods of the physical laboratory.

The method and true student spirit which characterizes Professor Max Müller's studies of the great religions of the world is identical with that of a Faraday or a Hertz, in the physical laboratory, and represents true science in its highest sense.

Under the title of What is Electricity? Professor Trowbridge has given us a thoroughly modern exposition of the principal phenomena which must serve as the evidence from which to answer this question; although he nowhere attempts to formulate a concise answer, (not even an indefinite one such as Professor Lodge has proposed), but rather presents us with the physical facts in a forcible and attractive manner and leaves the answer to the reader himself. Indeed any concise answer can hardly be hoped for, any more than it is possible to define that other mystery, gravitation. The physical properties and characteristics of electricity in its various manifestations can however be presented, and that is what Professor Trowbridge has done in an attractive manner.

The book contains twenty-two short chapters in which are treated besides other subjects and in a popular way, the measurement of electricity, magnetism, the electric current, sources of electric power, transformations of energy, alternating currents, transmission of power, transformers, wave motion, &c.

Besides these important subjects a very excellent chapter upon electric waves is given, in which the great experiments of Hertz are outlined, and another chapter is devoted to the electro-magnetic theory of light and the ether.

The phenomena of the "X" rays are also treated, and the author will be remembered as one of the earliest experimenters in this new and fascinating field.

The book is suggestive and cannot fail to quicken into action many who will read it. It also presents several very instructive examples and illustrations furnishing the mind with concrete conceptions, where mere verbal statements would fail. G.O.S.

A Dictionary of English and French Military Terms, by Albert Barrère, Professor of French, Royal Military Academy, Woolwich. Hachette London, 1895.

A Dictionary of French and English Military Terms, by the same. Hachette, London, 1896.

We have here a work in two parts by the professor of French at the R.M.A., Woolwich. Of the English-French portion, we need not speak, as it is of no special interest to our officers. The French-English volume, however, will prove useful, as far as it goes. This is not saying a great deal, but then the book does not go very far. Almost every subject of military science, to be sure, is represented; but only in part. The author gives no list of works searched for words, and it would therefore be unjust to speculate on the basis of his labors; but it is a fair inference from internal evidence that the work has in general been superficially done. For example, to an infantryman looking up the subject of small-arms, the nomenclature of which is by no means easy to master, Mr. Barrère's dictionary would be of very little help. Or take as a test, R. F. guns. Here Mr. Barrère is practically silent. If a second edition should ever be called for, certain errors ought to be corrected. Some of these errors will be noticed. *Adjudant* is not 'adjutant,' for the simple reason that the French *adjudant* is a non-commissioned officer.* The '*adjudant de la garnison*' does not assist the *commandant*, but the *major de la garnison*.

Assiette de casernement is translated 'seat apportionment'; the combination has, however, no equivalent in English, and the author's translation is inadequate; under the same heading, *assiette du logement*, has to do as much with regular barracks, as with "billeting area."

Batterie rapide, which Mr. B. makes "occasional light battery," whatever that may mean, is a distinct type of field work, to be rapidly put up, under circumstances of special haste. Why should *bourrelier* be a harness-maker for *pack*-animals alone? And why should "ricochet-fire" be the only equivalent for *bricole?* *Campement* since 1883 has been the party to select a cantonment or a bivouac, not the party to select a camping-ground. *Capitaine commandant* is not a "major." To call *capitaine en premier* "senior captain" is misleading. Mr. B's. "universal key" for *clef universelle* should be 'monkey-wrench.' The *chien* of the infantry rifle is now 'cocking piece,' not 'hammer'; to translate it by 'hammer' for *all* fire arms is incorrect. *Commissionne* means a good deal more than a re-enlisted 'landsman' or 'artificer.' *Conseil de discipline*, is not a regimental court-martial, but a court-martial that passes on the question of sending a soldier to the *compagnies de discipline* in Africa. To call a *quart de conversion* a "wheel of the quarter circle," is, to say the least, clumsy. *Coucher en joue*, is better understood as "to aim at," than as "to present at." *Demi-brigade* is the revolutionary name for regiment; to say that it consisted of three battalions in 1793, is to miss the point. *Dérivation* is properly 'drift,' and secondarily only, "deviation;" *dérive* is lateral right allowance, to correct for *dérivation*, among other things, but it is not 'drift.' *Encastrement de route*, and *de tir*, are better known as travelling-bed and firing-bed, respectively, than as "travelling hole" and "firing trunnion hole."

Maréchal des logis is a sergeant of artillery, as well as of cavalry, but Mr. B. credits the grade to the cavalry alone. He confuses "bridge by rafts" and

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* For some amusing examples of the mistake made by Mr. Barrère, see *Revue Rétrospective*, April 1, 1893, and July 1, 1893.

"bridge by parts," when he makes *construction d'un pont par parties* the building of a bridge by rafts. *Obus-fougasse* is not a "globe" filled with explosive. *Quartier* is a general term for quarters, barracks, etc., and its use not confined to the cavalry. *Rassemblement* is a command and movement of infantry, as well as of artillery.

Under *ressant*, what is meant by "wing" of a projectile? *Liberté de garrot* —not found in its proper place in the book, by the way,—is hollow of the pommel alone, and not also of the cantle. Mr. B. makes *vis-culasse*, the nut of the breech-screw, instead of the breech-screw itself. His distinction between *voiture* and *wagon*, that the former is a vehicle for men, and the latter for material and for animals is not always observed by the French.*

We point out these errors,—and we might add to the list—not in a spirit of mere criticism, but because some of them are serious, and others misleading. It would be unfair, however, to infer that Mr. B's. little dictionary is unreliable. On the contrary, it will be found in many relations, both accurate and useful, as far as it goes. For its chief defect is its limited range, particularly in respect of matériel. An appendix gives some useful statistical information about the French army.

The publishers have given the book an attractive dress: the print is clear, and the paper good.

C. De W. W.

Etude Critique des Opérations en Turquie d' Asie pendant la Guerre Turco-Russe en 1877-1878, d'après des Documents Officiels par un Officier Supérieur Turc. Constantinople, Otto Keil. 1896. Pp. 57, with 7 Maps and Plans.

In every one of the Turco-Russian wars the theater of operations in Asia, interesting as the events there often were, has been treated as secondary and subordinate by military history, and scarcely noticed in military criticisms on the campaigns. This is due to the fact that it has been less interesting to Europeans, but also to the fact that it has been actually less important.

Times have changed matters, however, and the political barometer indicates rather a high pressure on the side of Anatolia, which may bring forth serious disturbances in this corner of Asia now so well known,—Armenia.

The author of this interesting pamphlet, a Turkish general officer, presents here an able critical review of the events of the war of 1877-1878 on this side of the grand theater of operations.

In regard to the first offensive movement of the Russians he says:

"The Russians made all necessary dispositions to put their adversary, with every chance of success, in the interior line of operations.

"It must be granted that the Ottoman army would naturally be concentrated in the vicinity of Erzeroums. If the point of general assembly should not be found to be quite near to Erzeroum, behind Dévéboynou, the Turkish army could only be expected behind the barrier of Soganly-Dagh. Indeed, doubly protected by Kars and by the chain of Soganly, the western slopes of this chain would offer great advantages to an army on the defensive, and still concentrating. It would there command the road from Kars, Ardaghan and Bajesid. This probable position of the army of Monktar Pacha should, therefore, have been seriously taken into account.

"If Loris-Melikow, economising his forces properly, had been able to direct on Kars some 60,000 men and to fight the battle of Sivin with twice the numbers he had there, there is no doubt but that the campaign would have been terminated at one blow. But the Russians did not know how to profit by their superiority in numbers, and forgot that it is numbers which oftenest bring victory.

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* See *Revue d' Artillerie.* v. 43, p. 289.

"Another error, hardly less grave, was committed in opening the campaign, so to speak, by taking Ardaghan.

"Two fortresses barred the principal roads leading to Erzeroum, Kars and Ardaghan. In position, construction and garrison, Kars was the more important, and it was necessary to render it absolutely powerless before undertaking any other operations. Ardaghan, on the contrary, which had hardly enough men to defend it from direct attack, could have been rendered inert by a simple force of observation.

"With Kars taken, the Russians could have fallen with all their forces and an overwhelming numerical superiority on the Turkish army of occupation, and success would no longer have been doubtful, but this permitted the Turks plenty of time to arm Kars and to organize and concentrate their army."

The causes of the impotence of the Turkish offensive are thus stated:

"Two circumstances mainly contributed to this result, one strategical, the other tactical:

"Up to the middle of June the troops between Trébizonde and Batoum were raised by means of reinforcements from Constantinople to 30,000 men. And, as no serious enterprise by the Russians was at any time to be feared in this section, and therefore 8,000 to 10,000 men would have sufficed to meet the secondary enterprises of the Russians, the rest could have been used to reinforce the center at Sivin. By this means the army of Monktar Pacha would have counted 20,000 more. It would then have been possible to attack the Russians before Constantinople at the commencement of July with 50,000 or 60,000 men with very probable success.

"Again, if Ismail Pacha on the right wing had succeeded, in concert with Faik Pacha, in the feeble division of Tergonkassow during his difficult retreat, he too could have turned with his 20,000 men against the principal Russian corps at Alexandropol."

He shows very clearly that the Russians made quite as many (and perhaps much more serious) mistakes in strategy as the Turks.

It is a carefully prepared criticism of the operations considered, and a valuable addition to the military history of the Turco-Russian war of 1877-1878. The plans accompanying this pamphlet are excellent.

J. P. W.

Letters on Artillery by Prince Kraft zu Hohenlohe Ingelfingen, translated by Major N. L. Walford, R.A. Seccond Edition. London. Edward Stanford, 1890. Cloth 7s 6d.

The original of this excellent translation of perhaps the most valuable contribution to the literature of field artillery that has appeared since the war of 1870-71 was issued in the *Proceedings of the Royal Artillery Institution*, and has already passed through one edition.

The work opens with a careful analysis of the causes of failure of the Prussian artillery in 1866, and in conclusion he remarks that "during one phase only of the war, the moment when the 2d army appeared on the scene at the battle of Königgrätz, was it superior in number to the enemy's artillery, while the latter, on all other occasions, managed to bring into action twice or three times, even four times, as many guns as we, although the total number of guns of the Austrians was no greater than that of the Prussians." Moreover, "our artillery did not shoot so well as we had reason to anticipate," "again the renewal of expended ammunition was carried out on no regular plan, so that many batteries, owing to the want of ammunition, were not in a condition to injure the enemy; and batteries also constantly went out of action, either on account of the enemy's infantry fire, or in order to refit, when they would have done better to have remained in their position."

The use made of field artillery during the war of 1870 is then brought out in marked contrast, followed by two chapters contrasting the fire-effect of the artillery in these two great wars, and another comparing the losses of the artillery in guns. And here we find a remark that establishes a new principle: "In the former war it would have been considered as a disgrace to the artillery if they had lost their guns, in the latter the principle had been established that under certain circumstances it was an honor to have sacrificd them."

The explanation as to how it was that the artillery always came up at the right time is found in its advanced position in the order of march, and the fact that it was often made to trot for many German miles: at Sedan the corps artillery of the Guard marched 9 English miles at a gentle trot, in one spell.

In the account of how the artillery learnt to shoot we find this interesting statement, which should receive attention in our service: "I have never, up to the time of the introduction of rifled guns, known an inspecting General use the effect produced by the fire of a battery as a standard by which to judge of the excellence of its instruction." Are we not still in the days of smooth-bores in this matter?

The question of renewal of ammunition in time of war is still a burning one, and that together with the principles for the future employment of field artillery, discussed in the concluding chapter are to us the most valuable parts of the book.

The six folding plates appended to the volume are in keeping with the fine paper, the excellent typography and the tasteful binding.

J.P.W.

Krupp's Gusstahlfabrik. Von Professor Dr. Friedrich C. G. Müller. Düsseldorf: August Bagel. Pp. 169, large quarto. $6.25.

This excellently well printed and splendidly illustrated description of the great Krupp Gun Factory is a work of art as well as a scicentific treatise on the machinery and methods in use for the manufacture of armor and guns at this establishment.

The illustrations, both full-page heliogravures and wood-cuts in the text, are beautiful. They are the work of Felix Schmidt and A. Montan, and give a very graphic idea of the objects they represent, being scientifically as well as artistically *true*.

The subject-matter includes first a general description of the exterior of the works and their surroundings, the character of their products and the raw materials required to run them; then follows an outline of the chemical and physical processes in use, not indeed in scientific language, nor of much value to the metallurgist, but in ordinary words for the general reader. Many points of historical interest in metallurgy, gun-making and armor construction are brought out in the course of the account, and the illustrations include the latest forms of mountain, field, siege and sea-coast guns and carriages, fortifications, turrets, etc., and other armor protection, besides excellent views of the works themselves, externally and internally. The work concludes with a description of the charitable establishments erected by the generous owner and founder,—industrial and other schools, hospitals, dwellings and gardens, all for the benefit and use of the employes.

This volume gives us a very clear and comprehensive view of the extent and character of the domains of the great Steel King, and for the purposes of the general reader, enough of the methods is given to insure a fair understanding of what is being done there, while the illustrations, besides assisting the comprehension of the subject-matter add an element of beauty which is very pleasing to the eye. J. P. W.

Camps, Quarters and Casual Places by Archibald Forbes, LL.D. New York. The MacMillan Company, 66 Fifth Avenue. Pp. 344. Price $1.75.

The great war correspondent has lived a life of adventure, and has had an abundant and varied experience in camps, quarters and casual places, therefore, his collection of stories and incidents have all the interest of actual participation in the scenes depicted, by one who has traveled far and seen much.

"Matrimony under Fire" pictures a touching episode in the Franco-German war, painted with tenderness and deep feeling; and in "Miss Priest's Bridecake" we have an amusing account of the adventures of a born flirt, which ends as such stories should end: "To the best of my knowledge Miss Priest is Miss Priest still." A visit to the King of Burmah during the first Afghan campaign, is pleasantly told, and gives us the impression that "reverencing the golden feet," however interesting as a first experience, would not be an attractive daily devotion. The religious element in the German army, together with the functions of the *Feldpastor*, and the war prayers in the soldier's prayer book, make up the contents of a pathetic and reverent article, the moral of which is: "Would it harm the British soldier, think you, if in his kit there was a *Gebetbuch für Soldaten?*

Interesting descriptions of the Lucknow and Cawnpore of to-day, a character sketch of Bismarck, an attempt to picture the warfare of the future and an account of the deeds of military courage of royalty in 1870 and 1878, besides a number of other incidents and experiences, bring us to the two articles of particular interest to the military student.

"A version of Balaclava" is a valuable criticism of Kinglake's account, based on the work entitled *From Coruña to Sevastopol; the History of "C" Battery, "A" Brigade (late "C" Troop), Royal Horse Artillery*, to which Mr. Forbes adds, that "the author of the chapters was an officer in the Troop whose experiences he shared and describes, and is a man well known in the service to be possessed of acute observation, strong memory, and implicit veracity. The present writer has been favored by this officer with much information supplementary to that given in his published chapters."

"The Inner History of the Waterloo Campaign" is a summary of the new matter brought out in Ropes' *The Campaign of Waterloo*, briefly but clearly set forth, with other interesting matter bearing on the subject.

As a whole it is a collection ot varying character, diversity of theme, and difference of quality, part essay, part reminscence, part fiction, but all interesting and entertaining.

J.P.W.

Das Deutsche Reich. 1871-1895. R. V. Decker's Verlag, Berlin, 1895. Pp. xciv and 562. $1.50.

This history of the first quarter century of the German Empire gives, in a manner quite similar to Professor Andrew's history of the United States during the last quarter century, a résumé of the principal events of times too recent to have found a place in any other history, and yet of great importance to Germany, and in a less degree to the world in general.

It opens with one hundred and ninety-one official dispatches from the seat of war in 1870-1871, which constitute in themselves a briet and interesting summary of the events of the war, besides being a tribute to the army and a proper introduction to the history of the Empire which was founded on them. Each year is then taken up in succession, beginning with 1871, after the return of the troops from the war; the events are recorded in chronological order, always with special reference to the development of the empire,—its political and social life, the proceedings of its parliaments or the events transpiring at its courts.

The work is not only a history of the times, but also serves to show the labors of that great statesman, Bismarck, in guiding the ship of state safely through all the breakers, and to impress on the younger generation the necessity for a strong hand at the helm to preserve in the highest sense peace and freedom, and to keep open the road of progress.

The picture in general is painted with bold strokes and in broad outline, although here and there the details are worked up with great care, as, for example, in the portions of the text relating to the illness of the Emperor Frederick and the retirement of Bismarck. On the whole it is a valuable contribution to the history of our own times, and a worthy tribute to the soldiers who founded this great empire and the statesmen who established it firmly on its foundation.

J. P. W.

Verschlüsse der Schnellfeuer—Kanonen. Georg Kaiser, Professor at the Higher Artillery Course. Vienna: L. W. Seidel & Sohn. Pp. 115.

The second edition of this work, like the first (which appeared in 1893), is a supplement to the author's work, *Construction der Gezogenen Geschützrohre* (Construction of Rifled Gun Tubes); but whereas the former edition was a simple reprint of the articles which appeared in *Mittheilungen über Gegenstände des Artillerie und Genie-Wesens*, the latter contains all the later changes and improvements, and, in addition, the Krupp breech mechanism for field guns, the Armstrong screw breech-block with horizontal winch movement, and the arrangements to prevent hang-fire adopted by Skoda and Maxim.

The descriptions are clear and accurate, and are illustrated by twelve large plates of drawings, each containing from ten to forty separate figures. The following systems are included Hotchkiss, Skoda, Gruson, Gericke, Finspong, Krupp, Nordenfelt (wedge), Driggs-Schroeder, Sarmiento, Maxim-Nordenfelt (wedge), Maxim automatic (wedge), Canet, Armstrong, Maxim-Nordenfelt (screw), Dashiell, Scneider, Nordenfelt (1892, screw), French Navy, and Arent Silfversparre,

The position of the author as professor at the advanced school for artillery officers in Vienna is a sufficient guarantee of the excellence of his work. His published works have carried his reputation abroad and confirmed the high opinion his own country holds of him.

J. P. W.

Thoughts on Modern Tactics. Major-General H. M. Bengough, C.B., Commanding 1st Infantry Brigade, Aldershot. Gale and Polden, Aldershot. Pp. 50. Price: 1 shilling, 6 pence.

This small volume is a reprint of brief articles that appeared in the columns of the *Broad Arrow*, and are offered as notes toward the solution of the important question of modern tactics. They result from a study of the present condition of tactics and of the experience that the past few years have brought in maneuvers, as well as from a careful consideration of the military literature of the day.

The author advocates the *defense*, as opposed to the attack, for the English, *first*, because it will probably be forced upon them, *secondly*, because the defensive *rôle* is in accord with some of England's most glorious military traditions, and *thirdly*, on account of the composite character of the soldiers,—the Irishman, the Scot and the Englishman.

In the cavalry a better system of training, more practical work and greater strength of squadrons are advocated. In artillery tactics he maintains that close ranges are still practicable and advantageous. In infantry tactics he doubts the wisdom of doing away with supports, and believes in volleys up to close ranges; he urges considerable practice at long-range fire in target practice.

The entire subject-matter is of interest to all military men, being quite original and independent, well-digested and suggestive.

J.P.W.

Das Militär der Fünf Welttheile. Heinrich von Bülow, K. u. K. Rittmeister, Leipzig: Zuckschwerdt & Co. 1896. Pp. 171. 2 M. 50 Pf.

This work is a hand-book of the military establishments of all the nations of the world, including the smaller, such as Afganistan, Egypt, and the South American and African states, as well as the larger, comprising sixty-two in all.

The principal data given are the character and form of government, the area of the country, its population, flag, colors, etc., and finally the army, its system of recruitment, organization, composition and strength.

It constitutes thus an exceedingly convenient book of reference and the data appear to have been collected from reliable sources: principally the *Almanach de Gotha.*

J. P. W.

The Officer's Guide to Campaigning Equipment, how, where and what to obtain. Dudley Seagrim, Royal Artillery. Aldershot: Gale and Polden. Pp. 59. Price: 2 shillings, 6 pence.

The exigencies of our service often render it desirable that officers should be able to select at once a suitable campaigning equipment, and these notes, though intended for the English officer, contain many hints of value to us. The author has had the advantage not only of his own experience, but also that of several of the leading military authorities (General Lord Roberts, General J. J. H. Gordon, Lieutenant-General Sir H. E. Wood, etc.) as well as of some very distinguished travellers and explorers.

The subject-matter includes the personal and camp equipment of an officer (giving number of each article required, its cost and weight), medicines, mess camp equipment, list of provisions, packing of mess stores, and estimates for officers' messes of four, six and ten men for one month.

J. P. W.

Wilson's Cyclopædic Photography, by Edward L. Wilson, Ph. D. New York. Edward L. Wilson, 1894, Pp. 530.

Now that amateur photography has become more popular on account of the great increase in the number of inexpensive hand cameras, capable of producing fairly good pictures, a corresponding increase has taken place in photographic literature. Among these books the above volume deserves a prominent place as a book of ready reférence.

It is a compendinum in compact concise shape, of information in regard to all subjects concerning photography, and contains many valuable and interesting facts and many formulae, arranged so as to be immediately available.

Very often one has to go through many pages of ordinary photographic literature in search of some special information, which here he would find ready at hand. The readiness with which information can be found should recommend it to the busy professional and the experimenting amateur.

The volume is the result of years of experience in photographic affairs, and Mr. Wilson has succeeded in putting the material in such form as to make it what its name implies a veritable Cyclopedia of Photography.

J.K.C.

Photographic Mosaics, by Edward L. Wilson. New York, 1897. Edward L. Wilson. Pp. 288.

The thirty-third issue of this annual contains many valuable articles and specimens of the work of eminent photographers as well as articles and pictures by prominent amateurs, all of which are of value to those interested in photography.

The frontispiece is a photographic print on enamelled bromide paper, of four studies in posing and lighting by Falk. The review of the past year in photographic circles is replete with information, and comments on all that is new in photography, so that it cannot fail to interest the progressive photographer, who desires to keep up with the times.

The illustrations are good examples of the advances that have been made in processes of photographic reproduction, and are worthy of study by all workers.

J.K.C.

The American Annual of Photography and Photographic Times Almanac for 1897, edited by Walter E. Woodbury, F.R.P.S. The Scoville and Adams Co., of New York. New York 1897. Pp. 370.

This interesting and instructive annual makes its appearance once more in improved form and with a wealth of illustration, which is an object lesson in itself as to what photography has done for the illustration of books.

The reviewer has been familiar with the *Annual* for the last ten years, and has gotten many valuable points from its articles and formulae. The present issue surpasses any of its predecessors in beauty of illustration and in value of its contributions, and the long list of formulae cannot fail to be of use to those who make a serious study of photography.

J.K.C.

Compendium der Theoretischen Ausseren Ballistik, von Professor Dr. Carl Cranz. Pp. 508, with 140 figures in the text. Leipzig. B. G. Teubner. Price 20M. ($5.00).

The author of this stupendous work, which is intended to cover the entire field of theoretical exterior ballistics, is an instructor in Physics at the Upper

Real School and a tutor in the Technical High School in Stuttgart. The work is intended for the use of teachers in mechanics and physics at high schools; of artillery officers; of instructors at firing schools, artillery schools and war academies, members of boards of ordnance and testing boards; and of gun manufacturers and artillery engineers.

The work is truly a *compendium*, containing as it does the best work of the great men who have interested themselves in this subject, given in connected form and logical sequence, interspersed with much original work by the author himself. The opening section gives a brief sketch of the history of exterior ballistics from the time of Tartaglia, who published his work on trajectories in 1537, to the present moment, when (as Professor Cranz himself has informed us in a private letter) the Squier-Crehore Polarizing Photo-Chronograph is attracting great attention, and the projectile in its flight is being accurately photographed, even its oscillations being determined by means of a photographic apparatus in the projectile itself.

The second section contains the discussion of the trajectory without considering the resistance of the air, under various conditions, viz: constant initial velocity, constant angle of projection, sloping ground (including ricochet), and when curvature of earth (varying effect of gravity) is taken into account.

The next section is devoted to the most important laws of air resistance, including the latest investigations of Siacci, Zabudski, Vallier and others.

The integration of the differential equations for the movement of projectiles in air is next considered, followed by an account of the more important approximation methods (Didon's, Bashforth's, Siacci's, and others). The relation of the shape of the projectile to the resistance of the air, the deviations of projectiles, and their stability are discussed in interesting chapters.

The last five sections contain the practical applications, viz: the construction of firing tables, formulas for penetration of armor, the solution of ballistic problems, ballistic tables, and the mechanical aids to theoretical ballistics, concluding with an account of the latest instruments for measuring velocity, among which that of Crehore and Squier has a prominent place.

The work is not a mere outline of what has been accomplished in this field of investigation, but contains all the mathematics essential to a complete understanding of each author's special contributions to the subject, calling attention to imperfections and indicating future lines of investigation. Hence, it is invaluable to him who proposes to pursue some original course of study in this field, and his work is still further facilitated by an appendix giving full titles of all books and articles referred to.

It is a splendid work, executed in a masterly way, systematically arranged, well printed in clear Roman type, on good paper.

The historical introduction presents in a few bold strokes a clear outline of the great steps in the development of this subject. From the crude beginnings of Tartaglia and Benedetti the author passes to the first application of the mathematics to the problem of the trajectory by Galileo, who also called attention to the effect of the resistance of the air. "In 1707 the French Academy announced that the problem of the trajectory was (by the parabolic curve) so accurately and completely solved, that geometry could do nothing further for ballistics except to increase the accuracy of the instruments for pointing". Newton's investigations gave a new impetus to the interest in the subject and his quadratic law of the resistance of the air has held its own for many years. The equation of the trajectory was the next great problem, and was first solved by Bernoulli. Euler conceived the idea of considering the trajectory as made up of right line sections to simplify the solution, and General Otto carried out this idea and constructed a number of tables in which he calculated all the necessary ballistic elements, and these tables have been gradually improved and simplified by Didion, Morin, Piobert, Siacci, Bashforth, Zabudski and others, while from time to time new laws expressing the resistance of the air more accurately have been set forth.

The theoretical part is presented in proper sequence, logically and historically, beginning with the simplest conceptions, based on the simplest laws, and illustrated by many interesting problems.

The subject of the laws of air resistance is first considered theoretically, then follows a description of experiments to determine these laws conducted since Newton's, viz: Robins' Borda's, Hutton's, Thibault's, Didion's, Pioberts' those of the Metz Commission of 1856-1858 and of the Gâvre Commission 1859-1861, as well as the more recent ones. The various laws of resistance of air, are then taken up (Mayeski's, Hélie's, Bashforth's, Hojel's, Ingalls', Siacci's, Zabudski's and Vallier's).

The integration of the differential equations for the movements of a projectile is discussed with the same care, and the subject is opened with the assumption that the resistance of the air varies as the first power of the velocity, followed by the assumption that it varies as the second power, the third, fourth and nth power.

The section relating to the approximation methods is one of the best in the book and is well worth the most careful study, while that on the relation of the shape of the projectile to the resistance of the air, excellent as it is, lacks completeness: the author had not seen Captain Ingalls' essay on this subject, but proposes to embody it in an appendix now that he has it.

The causes of deviation of projectiles and the calculation of the amount of deviation, under various conditions, are set forth in a masterly way, and the section devoted thereto, one of the longest in the text, is another that will repay thorough study.

The most valuable part of the book for the practical artillerist is the latter part, relating to ballistic tables, tables of fire, penetration and ballistic instruments.

The application of the results of actual fire for the preparation of firing tables is clearly presented, opening with the arrangment of a program for the firing, followed by the method of calculating tables of fire, illustrated by a number of examples. The section on penetration considers the question mainly as relating to masonry, woodwork, earthen parapets, etc., with discussions of the laws of Poncelet, Euler and Résal; the empirical formulas for armor penetration are referred to, but only those of Krupp are discussed.

The method recommended and explained for the solution of the various ballistic problems is that of Didion-Siacci, and this is followed by a method (proposed by the author) for preparing ballistic tables, which he sums up as follows:

"It consists, *first*, in using, for the purposes of the artillery, as is now done. the tables of Siacci, Hojel and v. Wuich, or those of Otto, Bashforth, Chapel, etc.; *secondly*, in using, for purely theoretical investigations, according to the range of velocities, the corresponding law of air resistances, and in case of doubt the Newtonian law, or the new Chapel-Vallier law; and *thirdly*, for the purposes of the infantry, in constructing new empirical tables by firing with one and the same system of rifle and applying the Vallier tables, in order to obtain greater accuracy in the solution of the ballistic problems."

Under ballistic instruments are considered the barometer, thermometer, hygrometer, anemometer, ballistic photography, the old and new methods for the measurement of velocity, closing with an account of the Photo-Chronograph of Crehore and Squier.

The arrangement of the work, as will be seen from our analysis of its contents, is very convenient, the mass of matter being carefully systematized and brought under appropriate sections. The author shows a thorough knowledge of and familiarity with the entire range of literature on this subject, and has fully grasped the true significance and value of every new discovery and development, and the work is a history, a text-book, a dictionary and an encyclopedia, or as the author himself accurately designates it, a compendium of theoretical external ballistics.

J.P.W.

The Memoirs of Baron Thiébault (late Lieutenant-General in the French Army), translated and condensed by Arthur John Butler. In two volumes. New York.: The MacMillan Co., 66 Fifth Avenue. 1896. Price $7.00.

The work before us adds another to the long list of charming and interesting memoirs relating to the great Napoleon. The period covered in these two volumes is from 1769 to 1815, and, although written when the impression was fresh, they remained in manuscript for nearly fifty years after the author's death.

The translator (who is also the translator of the *Memoirs de Général Marbot*) regards these as the very best of all that crop of memoirs which have recently come to light. "Without perhaps having the genius for hair-breadth escapes which distinguished his junior contemporary General Marbot, Thiébault saw plenty of adventure; while, owing to his having come into the world fifteen years earlier, he is able to give not only a most vivid picture of the 'wild and whirling' years from '89 to '94, but also an eye-witness's account of the more creditable work done by the young Republic in protecting her frontiers. Again, though not placed like his senior, Barras, at the center of affairs during a critical period, his rank was sufficient to bring him frequently and closely into contact with the men who played the chief part in executing the measures which were changing the Face of France and of Europe. Over the last-mentioned worthy he has, too, the great advantage of being an honest man."

Thiébault was born in Berlin in 1769; in 1776 he came with his parents to France, but returned to Berlin in 1777 and remained there until 1784, when the family moved to Paris to remain permanently. His early military education, therefore, was under the great Frederick, and his superb troops were the models that impressed his youthful mind.

His life at Berlin, as well as the early days in Paris, are full of incident. One of the things which astonished him most and struck him most keenly was the sight of the series of promenades to Longchamp of which he gives us a vivid description. "During the three days which it lasted the whole world seemed bent on jollity." One of the carriages is thus described: "The body of the carriage was decorated with cupids, cyphers, and arabesques by a pupil of Boucher; the cushions were perfumed sachets. This was borne upon a gilt shell lined with mother-of-pearl and supported by bronze Tritons;

the naves of the wheels and the shoes of the white horses were of solid silver, the harness of green silk and gold. The lady herself wore flesh-colored silk tights covered by a garment of transparent muslin." The great Frederick was his standard by which to judge a king, so that Louis XVI fell far short of his ideal, and he relates a number of incidents to illustrate the character of that prince.

The beginnings of the Revolution, in which Thiébault took an active part, are depicted with delicate and artistic touch, bringing out the main events in a natural and extremely interesting way, enlivened by the little scenes in which he personally figured. In regard to the events of the sixth of October 1789, when the king came to Paris from Versailles, he remarks: "Still, I think that the end might have been equally well attained if M. de La Fayette had on that occasion shown himself to be as much of a general as he claimed to be."

The following incident is related of the King: "Just then a lady came through the gate. She had a pretty little spaniel with her, which, before she noticed it, ran close up to the King. Making a low courtesy, she called the dog back in haste; but, as the animal turned to run to its mistress, the King, who had a large cane in his hand, broke its back with a blow of his cudgel. Then, amid the screams and tears of the lady, and as the poor little beast was breathing its last, the King, delighted with his exploit, continued his walk, slouching rather more than usual, and laughing like any lout of a peasant."

The early part of 1791, when people "were conspiring amid laughter, staking their heads with a song, cutting each other's throat to a dance," makes a wonderful picture, quaint from its very contrasts.

In 1792, the character of the Revolution having entirely changed, Thiébault enlisted in the army and was on duty with the troops under Dumouriez; he was soon made a corporal and then a sergeant. The following year he was appointed lieutenant, and shortly afterward captain. While he was on a short leave at Lille, Dumouriez deserted to the enemy and Thiébault was arrested on account of the mention of his name in some intercepted documents. He was acquitted, however, and rejoined the army at Dunkirk. While there is not much said of the military movements, there are many interesting and entertaining reminiscences recorded of the life in the army. His first service in command of a company in presence of the enemy was at Le Quesnoy. In 1794 he was transferred to the Army of the Rhine. He was thus away from Paris during the height of the terror, but as he was often on leave of absence, and did not hesitate to make illegal journeys when he could not obtain leave, he was very frequently in Paris at this period, and has depicted many wild scenes of those days. His battalion having been disbanded while he was in Paris (without leave), he took part in the Belgian campaign on his own account, accompanying sometimes one division, sometimes another.

After the fall of Robespiere he became once more a part of the Army of the North, and participated in the misery ot the bivouacs of that icy winter of 1794, and finally in the capture of the lines of Breda. When his battalion was sent to La Vendée he obtained leave to go to Paris and was there assigned to the staff at the camp at Marley. He was in Paris on the memorable day when Bonaparte directed the firing on the steps of Saint-Roch, and took part in that combat in which the Republic won.

He was appointed assistant to Solignac, chief of staff of the first division, then encamped on the plain of Grenelle, so that he remained in Paris during the first part of the campaign in Italy, but at the end of a year he joined the army there on Masséna's staff. A number of brilliant adventures and interesting anecdotes of Kellerman, La Salle, Berthier and Augereau are interspersed with the simple facts constituting the recital of his own experiences and the general current of events. He was present at Rivoli and Tarvis, and his services promoted him to the rank of major. His position as staff-officer brought him continually in contact with the general officers, and often with Bonaparte himself.

In 1798 he joined Masséna (who had an independent command now) at Rome, and witnessed the mutiny of his officers there, which sent Masséna into retirement and left Thiébault without a chief. He remained in Rome for a time and gives a very interesting account of his life there, and of the two generals Saint-Cyr and Desaix. When the insurrection of Lake Trasimere broke out he was appointed chief of staff to General Valette and had some very interesting experiences during these troublous times. Later he served on the staff of General Duhesne, and assisted in levying contributions on the country. He did good service in the field too, and at the capture of Naples in January, 1799, he was appointed adjutant-general on the field of battle. After the retreat from Naples his health broke down and he was sent to Genoa and later to Paris for treatment.

Thiébault remained in Paris for some time and witnessed the return of Bonaparte from Egypt, after which he joined Masséna in Genoa. In describing his colleagues of the staff, he remarks: "It was owing to sheer bad luck that I remained a major-general for eight years (!)." Some interesting notes on the prominent men about him (Oudinot, Mouton, Murat, Junot and Duroc, besides his own chief, Masséna) light up the pages of his history, but as he devoted a separate work to the siege of Genoa his account here is very brief.

When Messéna was superseded, Thiébault obtained leave to return to Paris, and again we have some charming accounts of social life there.

His next post of duty was at Poitiers, where a corps was being concentrated, and soon after he was sent with a part of his command to Portugal, where he remained until June, 1802. He was engaged in some minor actions, and although it was a period of general inactivity for the army, he managed to have some thrilling adventures. The characters of Leclerc, La Salle and Savary are illustrated in fine pen pictures.

On his return to France, Thiébault was stationed in Tours, where he met Elizabeth Chenais, one of the cleverest and most accomplished persons in Tours' society, who a year later became his wife.

In the latter part of 1802 Junot offered him the command at Versailles and Chartres, which he accepted, but which he lost again because he dallied three weeks at Tours when his presence was required at Versailles. His next post was Orléans, where he made the acquaintance of Lord Elgin and General Count O'Connell.

Thiébault took his wife to Paris for the Emporer's coronation, and gives us a brief description of the festivities of that period. In September he was suddenly ordered on active service, and took part in the campaign of Ulm and the battle of Austerlitz, of both which he gives an intensely interesting decription. He was wounded at the latter battle, after doing excellent service, and returned to Paris, where he was soon after appointed general of division, and assigned as governor of Fulda, one of the districts of the recently occupied Prussian states, a post which he held until 1807.

When Junot was assigned to the command of the army in the Gironde, Thiébault accompanied him as chief of staff, and remained with him until his evacuation of Portugal. He was next appointed governor of Old Castile and remained in the Peninsula until after the fall of Rodrigo, when he returned to France on leave of absence.

In May, 1813, he joined the grand army at Bremen, and was placed in command at Hamburg. After Leipsic he returned to France, and later witnessed the return of Napoleon from Elba. The translation closes with a brief account of the end of Napoleon's career, although the original memoirs continue to 1820, and Thiebault did not die until 1846.

As a whole the work is as interesting as that of any of the writers on this period, the personal element, which lends such a charm to history, predominating throughout. The translator's work, as was to be expected, is excellently well done.

The dress in which the publishers have clothed these two entertaining and valuable volumes is one appropriate to the subject, and quite up to the standard which has gained them their well-deserved reputation with the public.

J.P.W.

Outlines of the Sanitary Organization of some of the great Armies of the World. By John Van Rensselaer Hoff, A.M., M.D., Major and Surgeon, U. S. Army.

This comprehensive and interesting essay was read before the Association of Military Surgeons and printed in the *Medical Age*. The data were obtained from the Division of Military Information, Adjutant General's Office, U.S.A., the Report of Captain Otto L. Hein, First U.S. Cavalry, Military Attaché at Vienna, Austria, the *Army Book* of the British Empire, 1893, and the *Medical and Surgical History of the War of the Rebellion*. The armies considered are those of Russia, Italy, Switzerland, France, Germany, Austro-Hungary, Great Britain and the United States.

The author gives us a clear and graphic description of the military sanitary organization of these armies, in detail and fullness sufficient to bring out their respective excellences and deficiencies, and at the same time prepare us for the changes to be desired.

In conclusion he says:

"The argument usually advanced in opposition to a reorganization is the fact that existing arrangements as respects subdivision of staff duties accords with the staff organization of the war period.

"This objection to change may be disposed of by the statement that the efficient armies of the world have little resemblance, as respects organization, to those maintained thirty years ago. Arms, equipments, systems of evolution, and method of supply have all been radically changed so as to make them conform to the new conditions of armament and the requirements of modern times. The general tendency is the concentration of chief authority, and an organization in each branch so close, thorough, and complete that co-operation can be had from each subordinate." J.P.W.

Questions and Answers on the Theory and Practice of Equitation for the Course of Squadron Training. Major A. J. R. Van Cortlandt. Gale and Polden, Ltd.: Aldershot. Pp. 81. Ninepence.

The object of this pamphlet is to facilitate the instruction of the men, by suggesting a method of instruction and calling attention to the essential points that should be brought out in this instruction.

The first section is an *Afternoon Lecture on Equitation*, the points to be emphasized being set forth in the form of questions and answers, and referring to such things as the fitting of the bit and curb, the use of the hands, the spur and the legs, etc., the aids for "Walk, March," "Halt," etc., and the various paces.

The second section treats of the *Practical Instruction of the Squadron in Equitation*, giving a list of the faults that must be overcome, and a system of field drill amplified from the Drill Regulations, with instructions for tent-pegging.

The third section comprises an *Afternoon Lecture on Outposts*, in the form of questions and answers, and the fourth a method of *Practical Instruction of the Squadron on Outposts*.

The book will be useful for the purpose it is intended to fulfill, viz: as an aid to junior officers and non-commissioned officers, and contains many little points that may be useful and suggestive to others.

J.P.W.

Report: America's Relief Expedition to Asia Minor under the Red Cross. Washington, D. C., 1896: The American National Red Cross. Price $0.30.

A special illustrated edition of the Armenian Relief Report of one hundred and forty-three pages, the returns from the sale of which will be used for the further relief of the Armenian sufferers.

Miss Barton's report is a most interesting account of the steps taken to obtain permission to aid the Armenian sufferers as well as the actual aid effected. In the course of it she says:

"But the facts are, that between the Archipelago and the Caspian seas, the Black and the Mediterranean, are to-day living a million and a half of people of the Armenian race, existing under the ordinances of, at least, semi-civilization, and professing the religion of Jesus Christ; that according to the stated estimate of intelligent and inpartial observers of various countries and concurred in by our own agents, whose observations have been unrestricted, from 100,000 to 200,000 of these persons, men, women and children, are destitute of shelter, raiment, fire, food, medicines, the comforts that tend to make human life preservable, or any means of obtaining them, save through the charitable beneficence of the world."

The pamphlet also contains the report of George H. Pullman, financial secretary, as well as the reports of relief field work in Anatolia. It is illustrated with photographs, wood-cuts and a map of Anatolia.

J.P.W.

Notes on year's Naval Progress, July, 1896. Office of Naval Intelligence, General Information Series, No. XV. Navy Department, Washington, D. C., 1896. Pp. 239.

This number of the General Information Series contains notes on ships and torpedo boats; on ordnance and armor: on small arms: on boilers; on voice tubes; on cellulose, and an account of the Naval maneuvers, 1895. A list of some standard books on professional subjects is also added.

A.H.Jr.

INDEX TO CURRENT ARTILLERY LITERATURE.

PERIODICALS CITED.

Abbreviations employed in index are added here in brackets.

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Captain James M. Ingalls, 1st U. S. Artillery,
Lieutenant Erasmus M. Weaver, 2nd U. S. Artillery,
Lieutenant George O. Squier, 3rd U. S. Artillery,
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EDITOR.

Lieutenant John P. Wisser, 1st U. S. Artillery.

ASSISTANT EDITOR.

Lieutenant Andrew Hero, Jr., 4th U. S. Artillery.

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FIELD SHRAPNEL AND THE CANNON OF THE PRESENT.

An analysis of our field artillery material based on the current discussion of "The Gun of the Future."

In the last number of the *Artillery Journal* (Nov.-Dec., 1896), appears the article of Major Jeannel, based on a study, by General Rohne, German artillery. It is the object of the present writer to apply the results already obtained in Europe as given in the tables and elsewhere in this article, to our own 3.20 and 3.60 guns and material, with the single proviso that the present limber be also used as a caisson body. The weight of the pole, neck-yoke, double-trees and fork will counterbalance that of the necessary stock, etc., adding 40 pounds for the necessary brake, also 30 pounds in the case of the horse artillery caisson body to insure the larger chest required. For the 3.60 gun the tread of wheel should unquestionably be 3 inches, which would add 16 pounds to the weight of wheel, which has been provided for also.

The factors which influence the effectiveness of shrapnel are stated as follows:

1. Number of bullets the projectile contains.
2. The penetrating power of these bullets.
3. The angle of the cone of dispersion.
4. The dimension of the objective, or target.
5. Angle of fall at point of burst.

nay first be stated that, in order to insure satisfactory ics for any shrapnel however perfect it may be in other ts, the spherical density must be high. This is the most tant factor of all. In Captain Metcalf's Ordnance and ry it is demonstrated that the spherical density of a pro- is equal to $\frac{8w}{d^3}$, in which $w =$ weight of projectile, and

$d =$ its diameter, in practice usually taken as the caliber of the gun.

In the table given by Major Jeannel, the Gruson 2.95-inch, 15.4 pounds projectile has a spherical density of 4.8, and the English 3-inch, 16 pounds projectile, 4.74. As this is an adopted service gun and projectile, this latter factor may be taken as our standard, and with it a 3.20-inch projectile would weigh 19.42, and a 3.66-inch 27.64 pounds, respectively, and so long as we do not exceed these weights we are not exceeding present practice.

We find, upon consideration of General Rohne's factors of effectiveness:

1. Number of bullets. It is obvious that this number must be sufficient to cover effectively the actual target we have to fire at in battle, i.e., if men, one bullet for each 8.25 sq. ft., which is the one presented by the average man standing, or if a horse and rider, 16.35 sq. ft. It is also obvious that the weight of the shrapnel under these conditions will depend upon the knowledge and skill of the constructors of the shrapnel. The lowest factor of efficiency given in Major Jeannel's table is about 28% for the older patterns of shrapnel,—our new 16.5-pounds shrapnel has about the same factor—while those of recent date give 42%, and in the case of the Hotchkiss *obus à mitraille*,* 66%, the value which should certainly obtain being 60%, which will be here used.

2. Penetrating power of the bullets. They must have sufficient penetration and energy to "stop" or disable a man or horse, and this depends upon the weight of the bullet and the remaining velocity of the projectile at battle ranges.

3. The angle of the cone of dispersion. This is governed by the size of the target, and distance in front of it at which the shrapnel should burst without too great loss of energy for the bullets. This angle can be regulated at will by giving the rifling of the gun a suitable pitch. This angle is also increased by having the bursting charge in front. But as this position not

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* In this projectile the endeavor has been to make the charge of balls itself (*la mitraille*) contribute to the rigidity of the projectile. For this reason the body of the projectile is built up of cast-iron layers carefully fitted and superposed one on top of another, giving the projectile a rigidity almost equal to that of a projectile wholly of cast-iron. Grooves cut in these layers insure their fragmentation into pieces that are of unequal sizes, it is true, but that depart as little as possible from the spherical form. These grooves in the layers hold the balls of hardened lead; the latter are protected from deformation in these recesses which exactly fit their form; they exert no pressure whatever on the envelope. The envelope is intended simply to hold the charge together during transport and during flight over the trajectory up to the point of burst; it can be reduced then to a very slight thickness: less than 2.5 mm. (.1 inch), while foreign field shrapnel have a thickness of 6 to 8 mm. (.24 to .32 inch).

Such is the principle which has governed the construction of the *obus à mitraille*. Thanks to it, this projectile has a rigidity that has stood every test. On the hardest ground the shell bursts at the point of fall by the action of the fuse, but does not break up by itself.

I am indebted to Lieutenant Andrew Hero, Jr., 4th Artillery for the translation from the French of this account of the *obus à mitraille*.

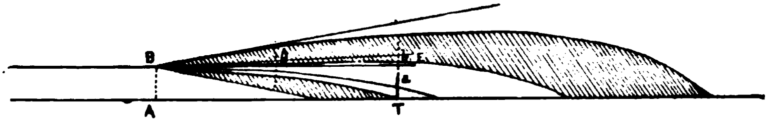
A.D.S.

only diminishes the velocity of the bullets, but also tends to destroy the regularity of the pattern, we find that a large majority of service shrapnel have the bursting charge in the base. If we place it in front, we must materially increase the remaining velocity, to insure effective bullets.

4. The angle of fall at point of burst. To insure the maximum efficiency for any given shrapnel, requires a certain definite angle of fall, for it starts at a minimum of effectiveness at the muzzle, where the trajectory is "*flattest,*" and the velocity *highest*, passes through a maximum, and then becomes zero when the velocity becomes so low as to render the bullets non-effective.

Major Jeannel simply states the old assumption that a high velocity and flat trajectory insures the maximum of effectiveness. This is the constant cry of the shrewd and voluble "promotors" for the various gun makers, who desire to increase their profits by selling to the army rapid fire guns originally designed for, and exceptionally well adapted for naval warfare with a different projectile.

It has been clearly demonstrated on many target ranges that a high velocity and a flat trajectory do *not* give the maximum of effectiveness, and the reasons are obvious to the careful investigator. Suppose for the sake of argument we concede the point to the limit, which is an absolutely flat trajectory, and as high a velocity as the promotors indurated conscience will assume, which will certainly be high enough even with a light projectile, to knock our carriage to pieces. We at once have the suspicion that we are to be taught the beautiful plan whereby we may "eat our cake and have it too."



Ta, target, average height of man 5 feet 7 inches.
ab, distance in excess of target covered by effective bullets.
B, point of burst.
θ, angle of cone of dispersion.
E, angle of projection giving greatest effective range of bullet.
AB, height of burst.

With a horizontal trajectory, as the axial bullet should strike the center of the target, the shrapnel must burst close to the ground, when it will not only be hard to accurately observe, but will also obscure the target.

With the usual weight of bullet and a high remaining velocity for the shrapnel—or initial velocity for the bullet,—to insure the maximum effective range for the bullet, its angle of projection will be about 1° 30′, and for obvious reasons this angle will practically remain constant for all ranges, the remaining velocity varying inversely as the range.

Supposing a proper burst, say 50 yards in front of the target, the angle subtended at the point of burst by the height of the target will be 2° 10′, and the height of *ab*, above the height of target due to *E*, or 1° 30′, will be 2.5 feet. With $\theta = 15°$, the horizontal length of the target will be 39.5 feet, or 22 files of infantry standing, at 22 inches per file. The area of the circle, or "pattern", to borrow a sportsmans term, will be 1225 square feet requiring 148 bullets to fill it, the area of a man being taken at 8.25 square feet.

We will then have 28 bullets in the total area of the target 5 feet 7 inches high and 39.5 feet long, and 12 in the extra space 2.5 feet high and of the same length. With a proper burst, which has been assumed here, we will always have 28 bullets hit the target. With the trajectory absolutely flat we have with this particular shrapnel, 12 extra effective bullets, and proportionately the same for different shrapnel. In other words the flat trajectory adds 8% of the total number of bullets, to the number of effective bullets in the shrapnel, the total number being 40, or 27%. This is the *minimum* number of effective bullets, given from the muzzle, where the velocity is highest, and the trajectory flat.

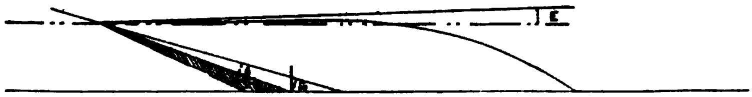
As would naturally be expected, we start with a minimum at the muzzle, pass through a maximum, and return again to a minimum when the velocity becomes too low to insure effective bullets.

The promotor claims that the effective range of the bullets is great with a high velocity and flat trajectory. Granted, but of what value with only 12 effective bullets? Again, the chances of hitting, which was unity for each effective bullet at the target or 50 yards from the point of burst, will become 1 in 4 at only 100 yards, with correspondingly reduced chances at greater distances.

Another claim of the promotor is that with these conditions, the greater range of effective bullets compensates for errors in burst of the shrapnel. This claim is also fallacious. Take the above shrapnel with 1500 and 900 f.s., then $\frac{1}{10}$ second error with the high velocity will burst the shrapnel at the target with 1 hit, or 100 yards in tront of it with 6 hits, and 3 additional bullets which would score 0.3 hit 50 yards beyond the target. With the lower velocity the shrapnel would burst 20 yards in front of the target, and would fill 12 men with lead, or it would burst 80 yards short and still give comparatively good results. Moreover, the high velocity reduces the length of time train for a second, or hundred yards, or other division, and thus renders it impossible to cut or set the fuze as accurately to start with, as can be done under the conditions of lower velocities.

Still another claim is that bullets are more effective by reason of ricochets. Battles are fought on grass, or cultivated lands. When such small and light bullets strike either, they become non-effective. But suppose a level cast-iron plane. We start with a pattern which covers directly every man in ranks within this pattern, and we prefer to wound rather than kill, as the wounded remain on the enemies' rolls and have to be cared for, while the dead are replaced in ranks. As all the bullets arrive at the target at the same time, we would with effective ricochets, score more hits on the same number of men, resulting in a loss and not a gain in desired results.

To determine the maximum results with shrapnel fire, we have the following. (See *Journal Military Service Institution*, March, 1892, p. 326);



$\theta =$ angle of cone of dispersion $=$ say 15°,

$E =$ 1° 30′, about $=$ angle to give greatest effective range to bullets.

$\omega =$ angle of fall.

We have as the angle of fall which will insure *all* of the bullets reaching the ground with effective velocities, $\omega = \frac{\theta}{2} - E$, or $\frac{15^\circ}{2} - 1^\circ\,30' = 6^\circ$. In this case we will still have 28 hits on the target, while all of the bullets passing over the target will reach the ground with effective velocities and energies. This condition gives the maximum results, and as the range and angle of fall increase, though we still will have every bullet reach the ground effectively, the beaten ground diminishes in area, until a minimum is again reached.

It is evident that what is desired in ballistics for field artillery guns is the *least* velocity with the greatest practicable spherical density, which will render our bullets effective at the greatest practicable range, and that any greater velocity at once entails a greater weight of gun and carriage, and consequently less ammunition, as the total load behind the team is a fixed quantity which we cannot exceed. For our present 3.20 gun this load is 3797 pounds. Incidently it may be stated for comparison that Major Jeannel takes 3808 pounds as the limit.

We have for the target with shrapnel, commencing with the 3.20 as a light field gun, which constitutes the divisional artillery, either artillery, infantry or cavalry in line. For the artillery we can readily cover one gun, as the front of a gun and its cannoneers and half the interval is only 41 feet. The area of the circle or pattern being 1320 square feet which, divided by the area of the average man taken at 8.25 square feet gives only 160 bullets, and even our present 13.5 pounds shrapnel is too heavy to accomplish this purpose, with its low factor of efficiency of only 37%.

But in the determination of our target, we have also to consider the infantry line, for which there is no limit to the extent we desire to cover, except as to the limit imposed by the weight of projectile we can fire from our guns, or carry with the battery in sufficient numbers, with a proper load behind our teams.

Obviously it is necessary to include two guns in line in our target. Commencing, then, on the right of the line, we have the cannoneers 2 feet outside the wheel, with the men added at a foot thick say 3; track of the gun 5; interval 45; the left gun and cannoneers 8 feet; and horizontal deviation of the gun at say 3000 yards as a mean battle range, 7 feet. Total 68 feet, or 37 files of infantry at 22 inches front per man, as the horizontal length of our target, which is the diameter of the circle, or pattern which we must fill up with bullets, at one for each 8.25 sq. ft.

This will necessitate in firing at a line of guns, aiming at the center of the interval. But with a proper peep for the sight, this can be done quicker and more accurately than aiming at a gun, as it is easier to bring two guns to the sides of the circle determined by the peep—when the gun is accurately aimed at the center of the interval—than to center a gun in this circle.

The target indicated is the best that can be selected as against artillery, as it is impracticable to include three guns in the target. As determined it is an excellent one against infantry which is one of the two principle targets for a light field gun.

The area of a circle whose diameter is 68 feet is 3632 square feet, which will require 440 bullets to fill up the pattern. Our shrapnel bullets weigh 170.8 grains, and with 60% efficiency for the shrapnel, the bullets will weigh 10.74 pounds. According to the tables the Hotchkiss 13.4 pounds *obus à mitraille* contains 66% of bullets, this may be a mistake, but Major Jeannel states specifically that these shrapnel are constructed containing 60% of their completed weight in bullets. With a factor of efficiency of 60%, the completed weight of our shrapnel will be 17.90 pounds, with a spherical density of 4.37. General Rohne deduced 3.20 as the proper caliber for his gun, and the Major that the metallic case with a charge of 1.34 pounds will not exceed a weight of 1.75 pounds. As our case for the same caliber weighs about 2.5 pounds, our "factor of efficiency" in cartridge case construction is about on a par with that for shrapnel construction—the worst possible. But allowing 2.15 pounds for the case, and 1.25 pounds for the charge, the round of ammunition will weigh 21.3 pounds.

Here it may be stated that if it is necessary to add 3 pounds in weight to our projectile with an increase of only 32 bullets of 41 to the pound, in order to secure a round of ammunition in one piece, this must be abandoned, and the cartridge and projectile must of necessity be separate. In constructing a round in one piece we have reduced the factor of efficiency for the shrapnel to 28%, and, according to Major Jeannel, this factor for the metallic cartridge case to 70%, which is simply barbaric in a nation of "born mechanics."

Of the 20 projeetiles given in the table but one is worse than our 16.5 shrapnel, and this is the 1877 Russian shrapnel of 15.07 pounds, in which the shell is no doubt made of cast-iron. The recent patterns of the ordinary shrapnel range in efficiency from 38 to 42%.

We should no doubt have a gun capable of rapid fire. Not that we are likely to use it as such once in a life time, but the fact of having it insures great moral value, and an enemy will not be apt to try to corner us. No commander in field artillery, whether captain or other, is ever going to allow an unaimed gun to be fired. To be able to fire 10 shots a minute is a good thing, but few artillerymen will ever see it done in battle.

The old S.B. has often been fired with double cannister 4 times in a minute at short range. Modern authorities state that the infantry can now drive off or kill the artilleryman at 1100 to 1500 yards, unless protected by first-class gun pits. Discount this by a half, and we are not then going to fire 10 shots a minute at their line lying down with nothing but heads visible. The moment we commenced, the infantryman would simply get under cover until we fired all the ammunition we cared to waste, and then come up serenely to continue the game of war. In the artillery duel at 2500 or more yards ranges, there will be no such firing, even when one side is in position and thinks it knows the range by measurement, etc. No artilleryman is ever certain of the range in battle, or that his shrapnel are bursting correctly. Rapidity of fire is, and will remain a question of correct aiming and observation.

For horse artillery it is generally conceded that the load behind the teams should not exceed 3600 pounds, or 600 pounds per horse. At the same time it is held that the number of rounds per gun carried with the battery should not be less than 160, as in service with cavalry there will be no ammunition train, and the horse battery must depend for its supply upon what is carried with it. If extended movements are to take place, when a larger supply of ammunition is necessary, the horse battery will draw three or more caissons from the corps ammunition train. With 12 caissions the battery should have 200 rounds per gun.

When it is desired to secure the maximum of advantages with the minimum of disadvantages, by the utilization of features already existing for the light field gun, for a horse artillery gun, we have two methods to choose from. First, as in the German and Russian services, by retaining the same caliber and weight of projectile, and reducing the weight of gun, material, and if necessary the charge and muzzle energy. But our 3.20 gun is already reduced to its lowest limits, and we must of necessity have recourse to method second, *i.e.;* retain the same weight of gun, caliber, etc., and reduce the weight of projectile in order to secure the necessary number of rounds and still maintain a proper load behind the team. It may be stated here that, under our conditions, this latter is by far the best of the two solutions of the problem. It gives a very heavy load measured by our past experience, but it assures us of a sufficiently powerful gun to compensate for the extra loads. At the same time, the charge and caliber being the same for the horse and light field gun, at a pinch, either the light or heavy projectile can be fired from either gun.

For this gun we have a different target, as the interval in horse artillery is 19 yards or 57 feet. Therefore, we must cover a front of 80 feet for two guns. This will also cover 27 files of cavalry, allowing one yard per file.

The area of the front exposure for a horse and rider is about 16.35 square feet. With a diameter of 80 feet the pattern to be covered is 5027 square feet, which requires 308 bullets to hit each horse and rider included within the diameter of the pattern. Twelve of the twenty shrapnel bullets given in the table weigh 200 grains, or more. It would therefore seem that this is the least weight of bullet with which we can expect to stop a horse. With this weight and 60% of efficiency, the shrapnel will weigh 14.37 pounds, and a round of ammunition 17.77 pounds.

For the 3.60 gun we will naturally have a heavy projectile. The heavy batteries will form the major part of the corps artillery and constitute the "back bone" of the artillery line of battle, and is the gun that must be able to fight all comers. We should, therefore, cover the front of two guns in horse artillery. By doing this we also cover 44 files of infantry, and at the same time have a margin of 19 feet for lateral deviation, which will assure the chances of hitting at extended ranges. This gun with a heavy shell of high spherical density, containing a large charge of high explosive, will be, with a measure of field artillery mobility, about as powerful a gun against field fortifications, as was the 4.5 inch siege gun. As it is also essentially a gun to fight with and against infantry, it is necessary to go back to the 8.25 square feet of a man in ranks, which will give 609 bullets to fill up the pattern. A bullet weighing 170.8 grains, as for the 3.20 light field gun, will give a projectile weighing 24.75 pounds. With 3.57 pounds for the case, and 2.40 for the charge, the weight of the round would be 30.72 pounds. This projectile is less in weight than the Russians have used for twenty years in their 4.2 inch heavy field gun, for which the projectile weighs 28.5 pounds, but its spherical density is very different, this factor for the Russian projectile being only 2.97. Like ourselves, the Russians have had a severe lesson in fighting against modern field works, and have, therefore, a very high appreciation of a powerful heavy field gun. For want of one during our last war we had recourse to the 20-pdr. Parrott, and the 4.5-inch siege gun used as position or heavy field guns.

In apportioning the loads behind the teams we have about 3600 pounds as a limit for horse artillery. Our 3.20 gun with 42 rounds of 13.5 pound projectiles gives 3797 pounds, or 4597 with 5 cannoneers at 160 pounds. The heaviest load for field artillery proper in our service during our last war was 5115 pounds, cannoneers mounted with knapsacks at 29 pounds, and strange to say this was for a caisson for the 3-inch rifle, a horse artillery gun used as a light field gun. For this gun the constructors under stress of urgent war demands, naturally adhered to the old

6-pdr. caisson with three chests with the usual 50 rounds for each. But with a rifle projectile weighing from 9 to 11.5 pounds, instead of 6, naturally the caisson weight was increased out of all due proportion to that of the gun carriage. We have the same result, however, in time of peace, when due consideration was possible, for the caisson with three chests each containing 42 rounds for our 3.20 gun, which weighs 4753 pounds, or with six cannoneers 5713 pounds as the load behind the team, 95.2 per horse, a load for seige artillery at a walk over good roads.

In every service present efforts are directed toward securing equality among the teams of a battery to the end that "twenty batteries may be able to cover at a fast gait from six to fourteen or more miles and then be able to come into battery simultaneously." It is obvious that there can be no equalization of the work of the teams without first securing a substantial equality for the loads for the gun carriage and caissons of a battery with the cannoneers mounted, which always determines the load at a rapid gait. It is therefore imperative that this equality as to loads shall be secured in the construction of the battery material and apportionment of ammunition, etc., carried.

It has been stated that for our "Gun of the Present," we can convert a limber into a caisson-body, adding the necessary weight for a brake, an extra large chest for a horse battery, and a 216 pound wheel for the 3.60 gun. Then under this condition as to our material "of the present" we obtain, with the projectiles, etc., as heretofore determined, the accompanying results (page 167).

It goes without saying that what is above indicated is entirely practicable as relates to our material, for it is all in existence now. The 3.20 gun carriage is equal to 275 f.t. of muzzle energy with an 829 pound gun, and for horse artillery is only required to stand 256 f. t., and for the field gun 261.

The same carriage with the 1281 pounds 3.60 gun, will stand much more than the necessary 325 f.t. to better advantage.

Especial attention is called to the fact that the loads for the 3.60 gun require a 3-inch tire. All heavy carriages in Europe have a tread of three inches or more. The light field caisson at 4648 pounds and 2.75 inch tread giving 421 pounds per inch of tire. With the same tread this load for the heavy field gun would be 462 pounds, which is an excessive load of this character in field artillery. The great road Engineer, Telford, limits such loads to from 373 to 560 pounds per inch of tire; the first for good *metaled* roads, the latter for first class paved roads. With a 3 inch tread after adding weight of wheels, the load per inch of

Weight of gun carriages and caissons equipped for field service.

	Horse	L.F.	H.F.
Caliber, inches	3.20	3.20	3.60
Gun, lbs	829	829	1281
Carriage, lbs	1120	1166	1198
Implements, tools, etc., lbs	32	32	32
Limber, lbs	957	957	989
Equipments, &c., lbs	71	71	71
Ammunition, lbs	639	767	983
Gun carriages packed for service, lbs	3648	3822	4654
Cannoneers 5 and 3 @ 160, lbs		800	460
Loads behind teams, lbs	3648	4622	5114

CAISSONS.

	Horse	L.F.	H.F.
Caisson body, brake @ 40 H.A. chest, 30 lbs.	1027	997	1031
Implements, tools, &c., lbs	129	129	129
Ammunition, lbs	834	767	983
Limber, packed, lbs	1667	1795	2043
Caisson packed for service, lbs	3657	3688	4186
Cannoneers, 6 @ 160, lbs		960	960
Loads behind teams, lbs	3657	4648	5146
Shrapnel or shell, lbs	14.37	17.90	24.75
Spherical density	3.51	4.37	4.25
Bullets, Number	308	440	609
Bullets, weight, gr.	200	170.7	170.7
Muzzle velocity, f.s.	1600	1450	1375
Muzzle enery, f.t.	256	261	325
Rounds in limber, Number	36	36	32
Rounds in caisson body, Number	47	36	32
Rounds per gun, Number	160	144	160
Number of caissons per battery	9	9	12

tire will be reduced to 429 pounds, or about the same as for the light field gun. This load for the horse artillery is 331, which will insure good running for the very heavy load, as compared with our old 6-pdr. or 3-inch rifle horse artillery carriage.

Evidently there has been no effort to "force a balance." The projectile weight is due to the target which is determined by the drill manual and the deviation of the gun. The weights behind the teams in horse artillery are substantially the same, and will still be so if we carry 48 instead of 47 rounds in the caisson body. In the light field battery, marching with cannoneers dismounted the caisson is 134 pounds lighter than the gun carriage, but at a rapid gait the caisson has the greater load, but by only 26 pounds. In like manner in the heavy battery the caisson is the lighter carriage by 368 pounds, but with the cannoneers mounted it becomes the heavier by 32 pounds. Thus the equalization of the loads for the carriages is most satisfactory.

Twelve caissons are required for the heavy field battery, chiefly for the reasons that as a field battery it must carry a due supply of shrapnel, and as it will also have to play the part of a *quasi* siege gun against field works, it must also carry a good supply of shell. Incidently it may also be noted that a battery of this character will require more cannoneers than the 14 for the light field gun. As only 3 can be carried on the gun carriage ordinarily, and 12 on the two caissons we have 15 per gun. At need 5 men can be carried on the gun carriage as with the light field gun.

It is suggested that this gun is too heavy. It will weigh 2511 pounds, our old 12-pdr. light weighed 2404, and was used with great facility even in horse artillery during the war. Were there really "giants in those days."

For comparison, we have the following:

	GUN CARRIAGES.			CAISSONS.		
	Horse	L. F.	H. F.	Horse	L. F.	H. F.
France	3516	4431		4048	5049	
Italy	2822	4276		3036	4686	
Austria	3421	4222		4288	4783	
Germany	3721	4277		4140	4655	
Russia	3667	4343	4719	4721	4721	4721
U. S. 1861	3185	3872	4457	3493	3811	3856
U. S. 1888	3751	3797	(1)	3818	4753	(1)
As above determined	3648	3822	4654	3657	3688	4186

(1) These loads have not been determined.

Major Jeannel states that "Moch assumes in his calculations that a caisson can be made in which the weight of ammunition will be from 40 to 50 per centum of the total weight." The weight of ammunition carried by the caissons as above gives; 40, 42 and 47%, respectively. The least load for any of the above European caissons is the German, 4655 pounds. With this load our caisson as indicated would carry 52% of the load.

Wheels are not going to be disabled by modern shrapnel fire, save by being hit by shell fired for range, or by an unexploded shrapnel, which are very remote contingencies. A single spare wheel carried on the forge and battery wagon, or stores wagon, will suffice for a battery. If carriages are hit and disabled as indicated, there will be plenty of spare wheels at hand on the battle field. Spare poles can be fastened to the sides of the stores-wagon body. The present 4 horse wagon to carry 3000 pounds will serve with horse artillery where every man carries his personal belongings on his horse. But with the other batteries it must be a 6 horse wagon driven from the seat on the body. This team can pull about 6600 pounds as readily as the artillery team can pull 4600. In a light battery there are 94 men whose knapsacks must be hauled, and @ 29. their weight is 2826 pounds. The officers' field allowance of baggage will be 650, total 3476 pounds. Tents, etc., will weigh about 500, spare poles 156, sundries say 468, will make the load carried about 4600 pounds, leaving about 2000 for the wagon.

In going back to the history of our old artillery material we find that the 3-inch rifles took the place of the 6-pdr. S. B. as a horse artillery gun, and weighed 830 pounds. When the 3.20 gun was designed it weighed the same—829 pounds,—and was of course essentially a horse artillery gun also, but with too great a caliber for the time, and the same as to the 3.60 gun. But whatever mistakes we may have made at that time have now proved very fortunate indeed for us. The advances in ballistic science and in the construction of shrapnel, have made the 3.20 caliber just about what is best for a light field and horse artillery gun, under the condition that the same gun must serve for both purposes, and the 3.60 has become the proper caliber for a heavy field gun.

Therefore, instead of speculating as to what the "gun of the future" should be, we can rest content in developing the latent powers for our present guns (within the limits now possible) in mechanical construction. That is, by dropping one ammunition chest and increasing the weight of the shrapnel to 18 pounds for the 3.20-inch gun and 25 pounds for the 3.6-inch gun and by making the other consequent changes suggested above, we shall place our field material at the very top of the efficiency list, superior in mobility and power to any system now in use, or projected in the recent discussion of "The Gun of the Future."

Captain A. D. Schenck,
2d Artillery.

SOME NOTES ON OUR ARTILLERY TARGET PRACTICE.

That trite paraphrase "it depends upon circumstances, terrain, etc." has been encountered too frequently and passed by too heedlessly to produce the impression that might be expected from slighter acquaintance with it. A personal experience with some of these circumstances is often required before we can know them, recognize their importance and become fully aroused as to how they shall be met; and fortunate is it when this experience can be had on the target ground, for what can not be accomplished then, surely could not be under the less desirable conditions of service.

For the past three years the light batteries have been firing shrapnel during target practice, and a growing familiarity with the projectile and its capabilities was to be expected.

The targets used last fall were such as to give good ideas of what might be expected, and with the firing experience that the batteries had had telling results might well be hoped for. But we all in turn had the opportunity to experience surprise when the result of a series of apparently well placed shots was announced, or when the destructive effect of some poor appearing shot was made known. The feeling of confidence in our projectile has been shaken, but it is of interest and instructive to know in what its weakness consists, and while criticising the material, not to loose sight of the manner in which it was handled.

The shrapnel used in '93 and '94 was the Frankford Arsenal shrapnel, that used in '95 was the electrically welded; the fuze has been the same throughout—the Frankford Arsenal combination.

On the target range we were convinced that the shrapnel of '95 was inferior to that used the preceding years, and an examination of the target records for the three years gives us conclusive proof that such is the case; and during the three year's firing each of the batteries has fired a series of twelve shrapnel at the same range, and the ranges were almost the same for the different years. The target has been 10 by 60 feet, the firing has been conducted in the most deliberate and painstaking manner; the result of each shot being known before another was fired, and poles 13 feet high planted at 10 yard intervals in front of and behind the target being used to assist the observers at the target in locating the point of burst.

In '93, of 24 shots fired at 2350 yards, all burst in the vicinity of where they were intended, 6 burst beyond the target making no hits, and the average number of hits for the remaining 18 shots was 38.

In '94, of 36 shots fired at 2000 yards two burst prematurely, one about 500 yards short of the target and the other in front of the gun; three others burst beyond the target. The average number of hits for the remaining 31 was 76.

In '95, of 36 shots fired at 2150 yards the fuzes blew out of three at the time they were expected to explode, three others burst beyond the target. The average number of hits for the remaining 30 was 41. The firing in '93 was the first the batteries had; range tables were computed and had not been checked by practice, many changes were necessary, and in fact the firing was experimental and gave information for subsequent use. This accounts in a great measure for the small average of hits made.

A comparison of the individual shots that have approximately the same co-ordinates of burst, referred to the target, have been made and the result tabulated. These shots are all line shots; the three shell fired just before the shrapnel, enabled the gunners to get the deflection with accuracy, and where the shrapnel was not in line no comparison has been made. The terminal velocity and the rate of fall for these ranges are also given (see table, page 172).

In every instance the number of hits has been less with the shrapnel used in '95 than with that of preceding years, and the maximum number of hits bears no comparison, though on a close examination it will be found that one-half expresses the approximate ratio in most instances cited.

There are two causes for this: The difference in the number of dispersed missiles and the greater cone of dispersion. The integral parts of the two shrapnel are about the same in number, but the electro-welded projectiles do not break up into fragments as completely as do the others.

With respect to the cones of dispersion, the plotted targets were examined for such as gave a great number of hits bunched together; the following were found and the result of the comparison is most surprising:

1895. Range 2150 yds. Terminal v. 933 f. s. Fall 3 feet in 10 yds.			1893. Range 2350 yds. Terminal v. 903 f.s. Fall 3 feet in 9½ yds.			1894. Range 2000 yds. Terminal v. 962 f. s. Fall 3 feet in 10 yds.		
Hits.	yds. Burst short.	ft. Burst high.	Hits.	yds. Burst short.	ft. Burst high.	Hits.	yds. Burst short.	ft. Burst high.
7	15	15	14	10	18			
131	20	3				252	20	3
42	30	15				48	30	15
29	60	20						
46	60	20	51	60	18	96	60	20
10	70	15						
19	70	15				45	65	20
25	65	18	51	60	18	110	60	15
9	80	18	65	80	20			
3	125	15						
8	120	25						
10	120	20	15	130	5	43	115	15
132	30	Burst on impact.				251	33	Burst on impact.
Shrapnel with maximum number of hits.								
132	30	Burst impact.				251	33	Burst impact.
121	20	3				252	20	3
106	30	8				314	10	7
170*	15	3				146	50	15
						148	60	10

* This shot fired at a range of 130 yards from target.

SHRAPNEL USED IN '94.

Shrapnel burst 15 yards short on impact, 302 hits in a target 10 by 15 feet. The diameter of the cone of dispersion is $\frac{15}{45}$ or $\frac{1}{8}$ of the altitude or range of the dispersed missiles.

Shrapnel burst 33 yards short on impact, 251 hits in a target 10 by 32½ feet. The diameter of the cone of dispersion is 32½/99 or practically $\frac{1}{8}$ of range.

Shrapnel burst 50 yards short and 15 feet high, 146 hits in a target 10 by 48 feet. The diameter of the cone of dispersion is 48/150 or again practically $\frac{1}{8}$.

SHRAPNEL USED IN '95.

A shrapnel fired 130 yards from the target burst 15 yards short and three feet high, 170 hits in a target 10 by 25 feet. The diameter of the cone of dispersion is $\frac{25}{45}$ equal to $\frac{5}{9}$.

It will be noticed that as the height of the target in all cases was limited to ten feet, the diameter of the cone of dispersion is taken to be the lateral dispersion in which direction the target was practically unlimited.

Taking the tactical size of a man, 28 inches by 5 feet and 10 inches, and the number of missiles as 200, there would be at least one bullet for the front covered by a man up to 50 yards from the point of burst of the shrapnel used in '94, and with the shrapnel used in '95 we would have the bullet per man up to 30 yards.

At 2000 yards the remaining velocity is 962 f.s.; a shrapnel burst at this point, the bullets weighing 34 to the pound and diameter of .526 inches, would have the necessary killing velocity of 500 f.s. up to 254 yards, so no consideration of this kind would make it desirable, even though it be possible, to delay the burst to within 30 yards of the target and to say the least the dangerous space from the point of burst should be as great as the distance corresponding to the least division of our fuze scale, which at 2000 yards is 52 yards for one-sixth of a second. This we see corresponds to the shrapnel of '94.

Can the shrapnel be used as canister? In "Artillery Circular I, series of 1893," published in Adjutant General's Office 1895, "Course of Instruction for Artillery Gunners," this question is settled and admits of no doubt. On page 226 after a description of both kinds of shrapnel, we read "shrapnel can be made to do duty for canister by reversing it in the gun, but should, of course only be used in an emergency." We are left in ignorance as to what emergency will enable us to reverse the shrapnel and insert it in the gun.

In the effort to use shrapnel as canister in our firing some wholly unexpected results were encountered, these had to do more especially however with the action of the fuze. Of two shrapnel fired striking the ground at 140 yards and 110 yards in front of the gun, neither one of them exploded from this impact; several hundred yards further on they struck the bluff and then exploded. The ground was level and of medium hardness, the gun was aimed point blank approximately at the places of contact. What was the cause of the failure to explode? It is thought that the trajectory being so nearly parallel to the ground contact was too delicate. If this be true then there is a zone limited by the maximum angle of graze and the minimum angle of fall in which the fuze will not act on impact. The extent of this zone might be of more interest than it could be of service, but at all events it would include that zone where no chance of uncertainty could be entertained.

The time of combustion of the time fuze is also uncertain.

Of 8 shrapnel fired at zero time,

1 exploded at a range of 10 yards.
1 exploded at a range of 85 yards.
3 exploded at a range of 120 yards.
2 exploded at a range of 130 yards.
1 exploded at a range of 160 yards.

Of 12 shrapnel fired at one-sixth time,

1 exploded at a range of 20 yards.
1 exploded at a range of 25 yards.
1 exploded at a range of 50 yards.
2 exploded at a range of 100 yards.
1 exploded at a range of 115 yards.
1 exploded at a range of 125 yards.
5 exploded at a range of 160 yards to 180 yards.

The mean point of burst for the fuze cut at zero is at a range of 111 yards and the mean error is 31 yards. The mean point of burst for the fuze cut at $\frac{1}{6}$ is at a range of 116 yards and the mean error is $47\frac{1}{2}$ yards, and in the first $\frac{1}{6}$ second of time the projectile moves about 94 yards.

In either case the same per cent. of shrapnel burst beyond a range of 100 yards, and there is practically no difference whether we cut the fuze at 0 or $\frac{1}{6}$. Firing at a target within 200 yards the result is most uncertain, if the shrapnel burst close to the gun the missiles will spread and the number of hits be very few; if it burst at or beyond the target the damage is likewise inconsiderable, and so we are compelled to believe that within 200 yards the shrapnel with the present time fuze is not to be depended on.

The irregularity in the time fuze at long ranges has been observed by us all, but when we consider that the origin of time measure, the marked zero, is most likely to have an error with a limit of range as much as two-sixth of a second uniformity of action can not be expected.

All of the deliberate shots at known ranges, these being the only ones in which the co-ordinates of burst could be obtained, have been carefully collected and the mean point of burst and mean error computed. The following table shows the result:

Year.	Length of fuze.	Mean point of burst. yds.	Mean error, yds.	Number of shots.	Range of target.
1893	$5\frac{1}{6}$	2254	40	6	2350
1893	$5\frac{2}{6}$	2317	35	18	2350
1893	$7\frac{1}{6}$	2890	32	5	3000
1893	$7\frac{2}{6}$	2970	50	4	3000
1893	$7\frac{3}{6}$	2980	32	4	3000
1894	$4\frac{3}{6}$	1910	23	9	2000
1894	$4\frac{4}{6}$	1965	35	10	2000
1894	$4\frac{5}{6}$	1988	52	5	2000
1895	0	111	31	8	
1895	$\frac{1}{6}$	116	47	12	
1895	$5\frac{1}{6}$	2047	24	5	2150
1895	$5\frac{2}{6}$	2097	34	14	2150
1895	$5\frac{3}{6}$	2104	24	6	2150
1895	$5\frac{4}{6}$	2104	26	6	2150

To give some idea for a comparison I quote the following from the *Proceedings of the Royal Artillery Institution*, June, 1892: "Mean error of fuzes taken from the practice reports of a well trained battery:"

Range, yards.	No. of fuzes calculated from.	Mean error of fuze.
600 to 1000	32	18 yards.
1000 to 2000	105	19.7 yards.
2000 to 3000	116	19.5 yards.

From an inspection of the above table it is seen that the fuze of '93 was decidedly a slower burning fuze than any since used; but more important, knowing the care taken to accurately determine the points of burst for the fuze cut at $\frac{1}{6}$, more credibility can be placed on the mean error than that determined elsewhere, and we see that for the 12 shots it is 47 yards or about $\frac{1}{12}$ of a second, this as before mentioned gives the difference of $\frac{2}{6}$ of a second as the extreme variation. It seems unnecessary to look any further for the cause of the irregularity of our fuzes when firing at the long ranges. The remedy for the irregular rate of combustion must be applied at the beginning of the time train.

Would it not also be better to have smaller division for the time train? Suppose our target be at 2000 yards, the ideal burst would be at such a point that, the cone of dispersions being as great as possible, all within it would be put out of the engagement. Taking the shrapnel of '94 our practice shows us there will be a bullet for the tactical front of a standing man if this burst be at 50 yards from the target. Suppose however that the target consist of kneeling figures or lying down figures, the point of burst would then have to be much nearer the target to accomplish the maximum result, and we are not able to get it there with the present scale.

If the burst be at 10 or 20 yards short the width of the cone of dispersion will be 10 or 20 feet, a waste of ammunition; decreasing the time one unit the burst is 60 or 70 yards back, width of cone 60 or 70 feet, and the probability of hitting greatly diminished by the scattering shot; moreover the loss in velocity of the small projectiles with such a point of burst would enhance too greatly the slightest intrenchments. By having divisions of twelfths, or what would be far more convenient, tenths, we would have a fuze that would enable us at all ranges to get much more nearly the maximum effect of our shrapnel, and with good material good results might then be expected, dependent upon the efficiency of the fire discipline of the organization.

The light batteries of our army are peculiarly dependent upon the captains for their efficiency. The lieutenants as they join the battery must be instructed and guided by the best system, and each one not left to his individual opinion of what is best, a system which would be non-progressive, every officer would act differently, and think of the resulting confusion, waste of time, ammunition, and uncertain result of bringing a battalion of 24 guns into action! Instead of being a unit, working to the same end, there would be a collection of individual efforts and lack of confidence. For example, a battery is called on to find the range. What method will be adopted, will it be the bracket, will it be by firing short and increasing the range by regular increments, will it be by estimating the range and firing to see where the shot strikes and then changing accordingly, will it be by range finder? The one that gives us the most accurate range in the minimum time is the one desired. But which is this, what system can be used most reliably, soonest and with the least expenditure of ammunition? Whatever methods were used in '95 were most unreliable, and it was nothing unusual to learn that a series of 12 or 15 shots had gone "all over" or "all way short" and this at ranges between 2000 and 3000 yards. The information that the ranging shots should give was lacking. The officer in charge of the firing was no more in error than many other observers in the immediate vicinity. The system of observing is the one generally used; there was no smoke to screen the targets, the terrain was all that could be desired, and all the conditions were favorable. What was the trouble? The poor shrapnel will not account for the errors in range, neither is it just to say that it can be attributed to the limited supply of ammunition and time. If others can succeed the only thing left for us to conclude then is that our methods were faulty (it can not be called a system for none was used). Generally it will require more than three shots to determine the range. In that case is it not preferable, would it not be preferable in any case where the shrapnel smoke can be seen, to make the last two or three shots of our ranging series shrapnel to burst on impact? This was done occasionally in the practice of '95 and it appeared to give satisfaction to those trying it, and it is of frequent application in the English artillery. This use of shrapnel can also be made to serve a double purpose. Colonel Murdoch, R.A. says: "Many officers who have had great experience consider that the surest and best method of obtaining the correct length of fuze is to get bursts on graze and shorten the fuze until bursts in the air are obtained. I am convinced that this is the case at long ranges, and at ordinary ranges a length of fuze that does not give a single burst on graze out of a considerable number should be lengthened. At indistinct targets this course is a necessity, at distinct ones it has the following advantages:

1. "The first two shrapnel further certify the verification of the range or accelerate that process, if the observing officer trust to them to take the place of the last two shell he would otherwise fire.

2. "Shrapnel bursting on graze have considerable effect, whereas any bursting far short are totally wasted."

Our shrapnel and shell have not the same trajectory, and in any case there is always the feeling that our first shrapnel fire is more or less of a range finder, and it is by all means an economy in time as well as more effective in results to include shrapnel in our ranging series.

No system of ranging can be of any use unless the accuracy of the guns can be depended upon, and the same system of laying them used. Not that it is desired to have bull's eye shooting, but good sharp uniform work, so that any one gun may give useful and reliable information to the others. There is a lack of confidence felt in the gunners due to the frequent changes made in the list. It would be remarkable to have the same set of gunners any two successive firing seasons, and usually one is well contented to have one or two old gunners whose uniform work can be relied on. Some time ago there was in use here at the post a Springfield rifle fixed to a frame that could be rigidly secured in the bore of the field gun. One hour's firing with this gun did more to bring about good and uniform sighting than one month's ordinary pointing drill, and the quickness and confidence it gave the gunners can never be reached by theoretical instruction.

To promote promptness in ranging and confidence in the gunners, a system something like the following might be of service. The battery is ordered to take some designated position, the ranging party if possible will have gotten the range or will get it while the battery is unlimbering; if this be impracticable the captain of the ranging battery will estimate it, and will designate the nearest exact hundred yards short of the measured or estimated range. Suppose the actual range to be 2830 yards and the captain calls it 2700 yards. He then goes to one flank and gives the command to fire. To observe and give this command are all that he has to do. As the range is designated all the guns are loaded and sighted upon the target with the elevations as shown:

(4)	(3)	(2)	(1)
2500 3100 (2850)	(2800)	(2700) 2750	2900 2850

The captain commands "2700 yards, fire," "2900 yards, fire," "2800 yards, fire," "2850 yards, fire." These commands following each other without a moments delay after the shot has been observed. At first the fourth piece is ready at 2500 yards in case the range is under 2700 yards. When the command for 2900 yards is given it is quickly raised to 3100 yards to be ready again; thus if the actual range be 3070 yards

2500 (3100)	2800 (3000)	(2700) 2950	(2900) (3050)

"2700 yards, fire;" "2900 yards, fire;" "3100 yards, fire;" "3000 yards, fire;" "3050 yards, fire."

The longer brackets could be any desired length, for instance up to 1800 yards, 100 yards; from 1800 to 2400 yards, 200 yards; and over that 400 yards. With a six gun battery the scheme for each gun would be much simplified. When the long bracket is established complete the ranging with shrapnel to burst on impact, or if some of the guns be already loaded with shell, use shrapnel as soon as is possible to complete the ranging. Four Springfield rifles, as mentioned above, to be used as sub calibers would be of inestimable value in perfecting on the drill ground any system. And where the supply of ammunition is curtailed so that it is impracticable to do both range finding and shooting at a target, would it not be profitable to expend all the ammunition in making the batteries proficient in range finding?

Lieutenant George F. Landers,
4th Artillery.

AN IMPROVED METHOD OF HAULING HEAVY GUNS.

The method of hauling guns described below is based upon that used by the contractor at Lime Point, California. It is therefore no experiment, and having been devised by a practical man of long experience in handling heavy weights it may safely be adopted by the artillery. In most respects it forms a distinct advance over our present methods, and will be found of especial use in cases where long hauls, steep grades, a lack of men or shortness of time make it necessary to discard the time-honored windlass and rollers.

Probably no point in the United States presents so difficult a problem in the hauling of heavy guns as Lime Point. The site of the battery is by far the highest in this country and one of the highest in the world. A winding road of a mile and a quarter in length, with a grade of 1 in 15 leads from the beach where the guns are landed to the battery. In order to gain length this road winds around a semi-detached butte, but owing to some sharp turns the gun and carriage were carried over the saddle connecting the butte to the main range of hills, taking the road higher up where it is comparatively straight. This necessitated taking the 12-inch B. L. R. up a slope having a gradient as high as five inches to the foot or 22½ degrees. For a distance of some three hundred yards the grade was nowhere less than three inches, ranging from that up to five. The first 12" gun was taken up a 6" grade for a short distance.

The essential features of this method of hauling consist in the use of a cradle sliding on greased ways, a simple turn-table and an engine with the usual tackle for power. So far there is nothing novel, but between this outline statement and knowing just how to actually transport a 12-inch gun up such grades a wide gap exists which it is my purpose to fill as far as I am able. Detailed drawings and a list of materials are also given which may be useful in case an officer is called upon to build the plant.

THE PLANT.

The Ground Ways.—These consist simply of two 10"x12" clear pine timbers laid flatwise and held apart by three 4"x6" spreaders evenly mortised about 2" into the ways. Three ⅝" tie-rods prevent spreading. This construction admits of being easily and quickly dismounted, hauled to a position forward of the gun and as quickly assembled. If knots exist on the upper surface of the timbers they should be cut down below the surtace so as to insure an even wear.

At least two sets of ways are provided, one of 60′ and one of 30′ and an extra supply of similar timbers.

When in use the upper surface of the ways is kept greased with beef tallow, tried out and applied warm by means of a brush. Linseed meal is then sprinkled on. This seems to sink into the wood and holds well. Mutton tallow is not suitable.

Against the forward end of the assembled ways is placed a loose 12″x12″ piece the use of which will appear later in describing the operation of hauling.

The Cradle.—For the gun carriage two 16-foot cradles are used, the base-ring and racer assembled being on the forward one and the other parts on the second. A stout wire cable passing around the base-ring and thence around the iron posts on the second cradle serves to hold them together in a sort of train. Dogs are also used for same purpose. This arrangement gives a short base and is adapted to facilitate turning on curves, but as the cradles are similar in all essential respects to that used for the gun only the latter will be described in detail.

The gun cradle is 30′ long, composed of two pieces of 10″x12″ pine united by three transoms each held in place by two ¾″ bolts as shown in the figure. The two forward transoms are placed close enough together to carry the four iron sheaves, each 12″ diameter and 2″ thick, held in place between 2″ oak plank let ¼″ into the transoms. Four ¾″ bolts hold the transoms together, the whole serving as the after block of the main tackle. The top of the cradle is notched ½″ to receive the ends of the transoms and the latter are similarly notched. The ends of all the transoms should project about 6″ for convenience in holding, etc. At the under side of the cradle the bolt holes should be countersunk 2″. The near transom is notched 6″ and bolted similarly.

To allow play the sides of the cradle are separated by 2′ 10″ as against 3′ in the ways themselves, measured on the inside.

On the inside of the cradle and projecting 2½″ below the bottom are placed "ribbons" or flanges of 4″x6″ stuff well secured by screw bolts. For a temporary cradle 10″ wire nails about a foot apart will serve. These "ribbons" extend only to within 6 or 8 feet of the ends. To prevent any possible spring it would be well to place two or three spreaders. These may be notched so as to rest loosely on top of the ribbons and made of a width to reach to their bottom.

The gun rests on 12″ beams placed loosely across the top of the cradle, the ends projecting about 2′ to give facility in blocking up and the use of jacks. Of course more elaborate bolsters may be provided and secured by bolts but this seems an unnecessary refinement. As it may be necessary to lift the gun these beams should not be secured to the cradle, and if any doubt about slipping occurs some blocks or chocks may be bolted behind them. The reason will appear when we consider the mounting of the gun.

The Turn Table.—This simple and very effective piece of apparatus consists of two flat pieces, 6′ square, the top one being 4″ thick and the bottom one 6″. These are made up of planks of the proper thickness bolted together as shown. When in use the interior surfaces are greased as explained for the ways. A heavy bolt of 2″ or 2½″ serves to hold them together when in use, and for a permanent plant the bolt should be securely bushed.

The engine is of the ordinary hoisting type, having a strong base and mounted on wheels. For heavy grades a 12 or 14 H.P. double cylinder engine having two drums and four "gypsies" should be provided. The drums should be placed low down on the frame, As only the gypsies are used in hauling, the drums may be dispensed with, but they will be found in the usual type.

For grades up to 2″ the style of engine does not matter much so that the choice of engine will depend on the ground over which it is to work. In any case there should be an excess of power rather than the reverse.

If the ground is soft dismount the engine and place it on 4″x8″ skids. and secure in place by cross pieces front and rear of base frame.

Two tackles, a "main" and a "preventive" are required, each of four-sheaved blocks reeved with 1200 feet of 4½″ manilla rope. The remaining parts of the plant are given in the table below.

OPERATION OF HAULING.

Although this will be complicated by conditions of road-bed, curves and grades, the two latter only are all that concerns us at present.

1. *On a straight road with a grade of 2″ to the foot or less.*—Here only the main tackle to the cradle is used. Supposing the gun and cradle are assembled in place on the further end of the long

ways. Across the forward end of the ways place the 12"x12" block before referred to and back the engine up against it. To this same piece strap the forward block of the tackle and take a sufficient number of turns around one of the gypsies. As the greatest strain comes in starting the gun it should be assisted by placing the jacks diagonally under the ends of the cross-bolsters under the gun, which pieces were left projecting for this purpose.

Hauling now proceeds until "block and block" is reached. It will be observed that by this method no anchoring of the engine is required and the only limit to the weight which can be moved is the power of the engine and strength of tackle. The engine, as it were, is pulling against itself. If any doubt exists about slipping, dogs may be driven into the ways behind the cradle on stopping, but before casting off always place the jacks ready for the start as described. On this grade no danger from slipping is to be apprehended, or at least the danger is small and the jacks afford ample security. Next, cast off the rope from the engine and fasten the forward block to the engine frame. By means of a suitable holdfast, placed in the line of travel, the engine now hauls itself forward to a new position unreeving the main tackle as it proceeds. The short ways (supposed to have been assembled in rear of the long ones) are now dismounted and the pieces hauled forward separately by the engine and assembled in front. The engine is now cast off from the holdfasts everything placed as before and hauling proceeds.

The above arrangement will give hauls of 30 and 60 feet alternately. It is evident that by providing two sets of short ways and assembling in the order (gun on short ways): long ways, short ways, we can get a haul of 90 feet for each position of the engine. This would always leave the gun on the short ways during shifting of the engine, etc., but it is doubtful whether the gain in time would amount to much, except possibly on a level or nearly level road where there is no danger of the ways slipping.

2. *On slopes of over 2" to the foot.*—Here special precautions must be observed and great attention paid to the proper placing of the ways and to their foundations. A level placed at right angles to line of travel and on top of the ways should always indicate a horizontal. If ground is soft and slippery blocking under the ways must be resorted to.

The gun is always hauled breech first. A second tackle, the "preventive" is also attached, its after block being fastened to the middle of a 1½" wire pennant the ends of which are applied over the trunnions. Little if any strain is taken on the preventive tackle it being used for safety only. If there are two shafts on the engine it would run to the one not in use. An additional precaution against slipping consists in the use of a beam of suitable length, one end of which is wedged in the muzzle and the other end left to trail along the ground behind at a suitable angle.

On stopping from any cause drive the dogs and place the jacks. Blocking should be used besides the jacks, placing it diagonally, otherwise the operation proceeds as in the first case above.

On slopes the height of the engine drums becomes a matter of importance. If these be too high up and the engine placed at the ends of the ways as described, the angle of traction may become so great that there would be danger of toppling the engine over. If by placing the engine on skids it is still too high, there is nothing to do but anchor the engine in advance in the line of travel and at a distance depending on the length of the tackles.

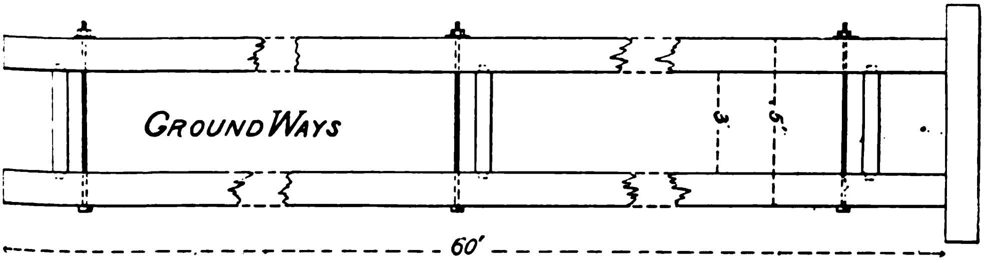
The holdfasts consist of "dead-men" placed in the line of travel. Turning points should be carefully selected beforehand and a dead-man placed just beyond each turning point. By attention to this the number of holdfasts may be reduced.

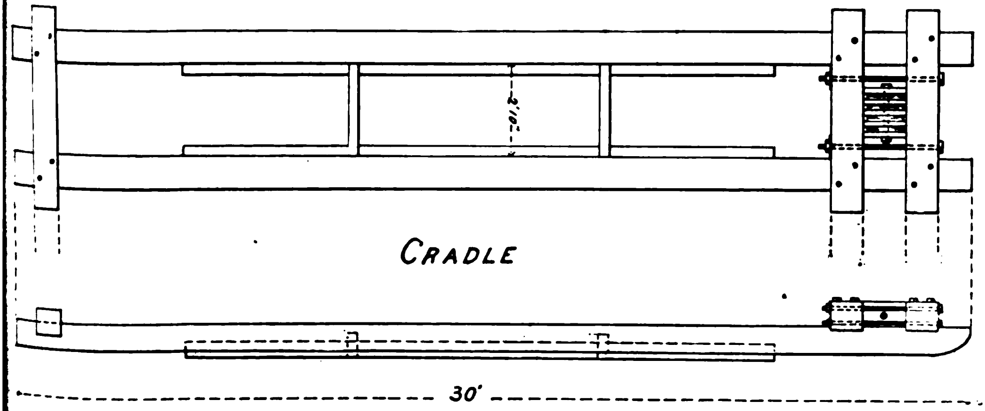
A "dead-man" consists of a 12" x 12" timber about 10' long buried horizontally in the ground, perpendicular to the line of travel and at a depth of five or six feet or well below the surface soil. Vertical planks or beams placed on the side of the pit would be of use in yielding soil. At the center of the timber attach two chain cables leading them out by a ditch cut for the purpose. These will come out of the ground some twenty or more feet away thus giving a pull more nearly horizontal and utilizing the holding power of the earth to the fullest extent possible. This arrangement makes a very secure holdfast. Haul the engine up to the chains, and anchor to them by a wire cable passing around the engine frame. Lead two pennants, one from each chain, under the engine and to their ends fasten the forward blocks.

It will be noticed that by this mode of holding we can pass over a "dead-man" and leave it in the ground for further operations; also that the pull is in line of travel, thus avoiding loss of power.

A similar method on the level would give longer hauls but as we would have to stop to shift the ways it is evident that little if any saving of time would result.

In a word, with proper kind of engine and tackle always haul against the ends of the ways.


GROUND WAYS
3'
5'
60'


2'10"
CRADLE
30'

Turning.—Whenever more than very moderate curves have to be passed the route will be divided up into a number of straight hauls and the gun turned by means of the turn-table.

When approaching a turning point some judgment must be exercised in placing the ways so that the gun will be brought to the center of the short ways over the turning point. Suppose gun on short ways. In front assemble the long ways, blocking up so that their forward ends will be 10″ above the ground, (the height of the turn-table), then haul gun on to long ways. The short ways are now assembled in front so that their center is over the the center of the turn-table. Block up to 10″ and haul until gun is centered on the turn-table. Remove blocking and turn gun. If everything is properly adjusted one man at the muzzle should be able to turn the gun. Then block up, place long ways in front inclining downwards and haul off by a reverse method. In this way all jacking up is avoided, everything being done by a simple haul.

If turn-table be of oak and the hole well bushed the gun can be safely turned without levelling up. However if gun is to be turned on a slope it would be better to level a secure foundation for the turn-table.

Mounting.—On arriving at the emplacement the same power is utilized in mounting the gun. To do this incline the long ways so upper ends rest between the cheeks of the top carriage replacing the spreaders and tie-bolts by a shorter set provided for the purpose. Bring gun up in prolongation of these ways, turning it if necessary. Jack up the gun and similarly narrow the cradle and short ways, substituting short bolsters under the guns for the long ones heretofore used. The engine is now placed in a convenient position in rear of the emplacement and by an obvious arrangement of tackle the gun is hauled into place.

Generally.—The 12″ mortars need not be hauled separately but may be formed into trains each mortar being on a short cradle. Similarly with guns of less than 12″ calibers, carriages, etc.

To work the plant one officer and a detachment of eight men are required.

A complete plant as described, designed for the heaviest work will cost from $1500 to $1800. In other words, for less than the price paid in some cases by contract to haul the 12″ gun and carriage from beach to emplacement a plant can be provided which will last indefinitely.

BILL OF MATERIALS REQUIRED FOR A COMPLETE PLANT FOR THE HEAVIEST WORK.

1 14 H.P. double hoisting engine, 2 cylinders, 4 gypsies, on wheels, as described.
5000 feet pine, 10"x12".
4000 feet blocking, pine, assorted.
4 pieces oak, 4"x6"x20' (or can use pine).
250 feet oak or pine plank, 6" thick, 200 feet oak or pine plank 4" thick (for ribbons).
8 pennants, 80 feet, 1½" flexible steel-wire, 12" eye.
12 chain shackles.
6 pieces chain, 2", each 20'.
4 hydraulic jacks, 15 ton.
12 iron dogs, 1¼"x16", square.
1 main tackle, 1200' manilla rope, 4½" or 5".
1 preventive tackle, same.
2 10" blocks, 4 sheaves each.
1 coil, (about 700') manilla rope, 3½".
1 2" snatch block.
1 1½" snatch block.
1¼" snatch block.
3 water barrels.

An assortment of bolts, tie-rods and screw bolts as described, dimensions of which can be taken from the figures.

With the advent of new and heavier guns new modes of transportation must be devised and new and suitable plants provided for the work. Every heavy artillery post should be provided with such a plant at as early a date as practicable. For speed and safety combined with power to overcome heavy grades, I know of no method as good as the one described above. At nearly all of our Pacific Coast forts we find long hauls and heavy grades. The same is true to a less extent in many of our eastern forts.

Guns should be consigned to the artillery branch and should come under its jurisdiction from the moment they arrive on the reservation. The responsibility for their care then devolves upon the artillery from the outset. This branch should not only mount all of its guns but should transport them to their emplacements. No work in time ot peace, except target practice, is of more value in the technical training of the artillery officer and man. In time of war this work will doubtless devolve upon the artillery and methods and plants should be carefully devised beforehand and practice had with them,—not merely drill practice but actually doing the useful work with the guns as they arrive.

This work clearly falls within the province of the artillery and at the rate guns and emplacements are now being provided both the transportation of the guns and their mounting can be done by the present artillery forces,—provided of course that suitable plants are provided for the work. The above plant requires so few men that the work need not interfere with the usual drills and instruction.

1st Lieutenant ELMER W. HUBBARD,
3rd Artillery.

THE PROGRESSIVE DEVELOPMENT OF THE SCHOOLS FOR ARTILLERY PRACTICE IN GERMANY.

Translated from *Revue Militaire de l'Etranger*, November, 1896.

In a recent article on the Field Artillery in Battle in Germany and Austria, the *Revue Militaire de l'Etranger* gave the principles which actually exist in the use of field artillery in those two countries on the battle field.

One of the conclusions from a study of this article is that the German field artillery tactics can be summed up as follows: To open the way for the infantry and to facilitate the accomplishment of its duty everywhere and always. That is to say, whatever may be the real value of fire, it is always the foot soldier who alone is able to decide the contest, by taking and keeping possession of the ground.

The shock of the foot soldier is as indispensable to-day as formerly; and also to-day as formerly, the only use of fire is to drive the enemy from a position which he is resolutely defending; the assistance of infantry is necessary after that. In our time, the artillery remains as in time past, an *auxiliary;* its role has increased because its perfected material gives it a more extended, more powerful and more rapid power, which power is found in the cavalry sometimes, in the infantry always.

Such are the German ideas; they are found everywhere. Especially in their regulations and in their military works, the Germans have insisted upon the intimate relations of the artillery with the other arms, of its dependant arm rôle, and if they insist so much upon this subject, it is because the specialization of artillery was more marked in Germany than anywhere else up to 1870, that it nearly cost them the victory in 1866, that they attribute to its disappearance a great part of their success of 1870-71, and that they wish at any price to avoid the return of it.

But who then, in actual warfare, would think of the resurrection of this specialization, of this independence, of arm? Is not the indispensable element of victory in the absolute union of the three, of the four arms, in fact in the spirit of all? What chess player wishing to beat a formidable adversary would seek to use his men independently of each other, instead of combining them?

The watchword must be aid and protection.

The Germans think that, in order to respect this watchword in war, it is necessary to practice it during peace, so they have formed fourteen grand camps of instruction in which the different arms assemble to learn how to maneuvre and work together; in the camp of Malmédy last July, infantry, cavalry, foot and field artillery, railway troops, etc., took part in exercises in which the artillery actually fired war ammunition, including the torpedo shell.

It is worth noticing that this actual firing of the artillery, combined with maneuvres, is becoming more and more frequent, especially in that which relates to field artillery.

The Germans endeavor to have this artillery practice firing under war conditions on a varied terrain during the five days preceding the grand autumn maneuvres.

It can be said of field artillery that its tactics is composed of two elements, the drill and the firing. The first can be studied everywhere, in every movement, in all maneuvres and especially in the grand autumn maneuvres; the second is studied in the schools when the annual firing is held. But the union of these two elements, drilling and firing, which ought to constitute the perfection of tactical instruction of artillery and render the latter entirely suitable in battle, is still little practiced; too vast fields are necessary in order to have a maneuvre with actual firing.

Nevertheless it has been considered advantageous for the artillery to go out from time to time, and by firing make the conditions as similar to war as possible.

In spite of these material difficulties, this great preparation of the artillery for wars will necessarily attract, more and more, the attention of countries as it will be the artillery that will decide many battles in the future.

To maneuvre well, to shoot well, to know how to discern what movement and what fire is suitable to the tactical situation of the movement, are qualities that artillery ought to seek to acquire in order to be worthy of the great rôle which henceforth will belong to it.

Owing to the importance of this subject, it has appeared interesting to us to show, by a glance taken at the past and by the consideration of the actual state of things, the considerable progress made in the last 30 years by the German artillery, and this in consequence of the progressive and constant development of two military institutions to which the artillery officers go three times during their service for the purpose of instruction; these are schools for field artillery practice and for foot artillery practice at Jüterbogk.

Very little will be said of the school of fire of foot artillery, as it is especially the school of field artillery which we wish to describe; it is proposed to show how this school started as a result of the ever increasing importance of artillery fire, its constant development and the important place it occupies in Germany to-day.

To connect the remarks which follow with those which have gone before it will be necessary to determine whether this school has followed along the lines on which it was established, viz: the study of the different kinds of fire, their improvement and instruction therein pure and simple, for it seems that for many years the practice of firing was not separated from maneuvering and drilling. Independent troops, which have been increased from time to time, have been assigned to the school, constituting units tactically instructed and drilled, which have permitted, and still permit it to give life to its instruction, real life, by combining the drills and the firings.

The history of the field artillery practice school, the history of the foot artillery practice school, various German periodicals, many works of German literature, joined to official documents (rules and instructions for German artillery) have furnished the data for this article.

Until 1860, artillery fire had little importance in Germany. Canister firing was the only thing that could be depended upon; the battery approached quite near its objective and fired; to do this it was necessary to have a good deal of bravery and to take almost no aim. No attempt was ever made to fire with any accuracy or to great distances, first because the errors were so great between shots that nothing could be concluded in observing the point of fall of the shot, and secondly the pieces could not carry very far.

Fire instruction was quite neglected in the German artillery, the batteries practicing only seven or eight times per year, and then more to accustom the men to the discharge of the cannon than to exercise the officers in the rules of fire.

The objects fired at consisted of targets which did not in any way resemble things met with in war. It was always the same range and the targets were always put in the same place, at carefully measured distances. During the fire observers close to the targets indicated by means of signals, the place where the shot had struck, but battery commanders did not attempt any changes as a results of these reports.

The inspector generals especially directed their attention to corrections in the drill, the alignment of the pieces, the rapidity of going into battery; they did not worry themselves with the manner in which the fire was conducted or the results obtained.

The importance of knowing the distances and of observing the points of fall commenced to attract attention only on the introduction of rifle cannon.

Under the influence of the appearance in the French army of cannon with four lands, a cabinet order of May 7, 1859, prescribed the immediate construction of 300 rifled pieces; German artillery had its first rifled pieces in 1860. But the procedure of fire was not changed immediately, and in 1864 the Germans saw from the results of the fighting before Duppel that they had not made the best use of their cannon.

It was seen that the most important thing to do was to teach the officers the rules of firing. The cannoneer, a mechanical instrument for the service of the piece, must receive from the chiefs the mathematical information for carrying on the firing.

The idea of an artillery practice school for the instruction of officers originated in this way. General Hindersin, becoming the first Inspector General of Artillery, took upon himself the task of keeping up this school and of developing it.

The artillery practice school was first organized in 1865, as an experiment. The Prussian Chamber (Landtag), then in conflict with the Government, not having voted the necessary funds for running the institution, the officers who came were *volunteers* and *themselves served the pieces.*

Thus it was that in the year 1865, a few captains and lieutenants of each artillery brigade were drilled in the management of the new rifled pieces and in the corrections necessary to be made during firing. These officers, going back to their respective garrisons, gave the benefit of their experience to their comrades.

But the war of 1866 broke out and these first manifestations of a school of fire so shortly organized did not make themselves felt. There was yet no method of fire and each battery was left to the discretion of its captain, who was to take the initiative and act according to his own personal ideas and without any unity of action. So, notwithstanding the large proportion of rifled cannon (10 batteries to each army corps of the 16) the German artillery did not give the results that were hoped for and that were expected from it.

The German artillery then felt the necessity of developing at home that science of fire which it caught a glimse of abroad for the first time; the final objections of the opponents were overcome and the artillery practice school was officially created by a cabinet order of July 4, 1867.

Toward the end of 1867, the armament of the field artillery with rifled pieces was complete, and in 1868 all the artillery brigades were able to practice with the new material. The artillery school made its influence felt in this way, that the officers who had taken a course in it did, at the practice firings before their regimental comrades, experimental firing in order to give an example of the benefit they had derived.

At the end of the year 1868, the artillery school and all the artillery brigades were called upon to submit reports and suggestions for establishing rules of fire in order, if possible, to increase the interest of the officers in 1869 and 1870.

These were the rules that the German artillery employed during the war 1870-71. They were simple, as everything is in its infancy, but they were practical. For example, the rule for firing upon a moving target advancing on the battery was as follows: The distance was estimated and a shot fired short, the point of fall was marked; when the enemy arrived at this point the battery opened fire upon him and kept it up until it was seen by the smoke from the bursting shells that he was out of range, then another shot would be fired to strike at a less distance than the first and the point marked upon the terrain; when the enemy reached this new point fire was opened on him again, and so on.

It was easy and the results were excellent as compared to those of the campaign of 1866. But still the fire of each battery was independent of its neighbor's. The artillery group existed as a unit for maneuvring, but its commander not having sufficient technical knowledge of firing, the group fire was not possible. It was necessary to wait 13 years before there appeared in the German regulations rules relative to group firing.

After the war of 1870, the artillery, which had played an important part in it, was naturally the subject of a great deal of attention. Changes in the material went rapidly on, since it was in 1873 that the new system of field artillery was approved; and it might be stated here that few modifications were made from then until 1891, the time when it was decided that the metal of the cannon must be changed. But nothing having been changed in the general outline of the piece it can be stated that, at the present writing, the system of 1873 is still in force.[*]

The methods of fire were less rapidly changed from now on. With the new material, model '73, appeared indeed new rules for fire more precise than the preceding ones, introducing for the first time the idea of getting the range by two trial shots, one over the object, and the other short,[†] but these rules have since been made and remade many times; there have also been many manuals of fire, themselves modified quite often.

These rules of fire enlarged by the school for artillery practice bring us quite naturally to the object of our paper, the development of that school.

The history of the artillery practice school can be divided into two very distinct periods; the first from 1871 to 1889, all of study and consequently of stagnation; the second from 1889 to 1896, all of progress, almost daily and constantly incrasing.

Period from 1871 to 1889.—The artillery school, common to the field and foot artillery, was installed in the Tegel polygon near Berlin; it included only one battery and a company of instruction, which, quartered far from the field of fire, lost an enormous amount of time in going and coming.

The questions of fire took up the greater part of the instruction and occupied three days of the week, a day was set aside for a war game, and the other two days were used in visiting gun shops and in taking part in the work of the experimenting committee.

There were every year two series of lectures of four and a half months each, each course including about thirty officers.

Put at first under the authority of the president of the experimenting committee, the school was not relieved from this tutelage and placed under the direct authority of the inspector general of artillery until 1877.

Notwithstanding this emancipation which seemed to indicate the launching of the school into a more practical way, it was endowed with too small a field of fire and too few troops of instruction, and was therefore hardly able to better itself. And then the methods of fire were not well established; the employment of shrapnel was not known and was still being experimented with. Not being well advanced in firing with a battery no attempt was made to have group firing. However, commencing in 1879, a few field officers came to pass a month at the school, though at irregular intervals separated by many years.

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[*] In 1873, the Germans had adopted 2 field cannon: the light field cannon, model '73 (horse batteries), the heavy field cannon, model '73 (mounted batteries). In 1888 the first was suppressed and the heavy cannon having been lightened 30 kilogrammes was given to all the field artillery (Model 73/88). Finally in 1891, nickel-steel began to replace the metal of the cannon of the model 73/88. The new pieces are called field guns, model 73/91. They weigh 22 kilogrammes more than the cannon, model 73/88.

[†] This was the introduction of la fourchette which exists to-day in the rules for arlillery firing.

In 1883 *l'aide-mémoire d'artillerie* contained the first rules for group firing:

"Each battery ought to direct its fire on the object assigned to it, but it ought to utilize the results acquired by those which were already in position. As soon as a battery narrows down its fourchette, it should make known the distance obtained to the commander of the group; the latter would compare the reports sent him and if necessary order a few volleys, etc."

In 1886 Major H. Rohne, who had been a professor in the artillery school for three years, published a paper on the employment, from a technical point of view, of great masses of artillery which, though not answering to its title, since it did not treat the subject beyond the Abtheilung, discussed the subject that was attracting a great deal of attention and also the tendencies of the school.

This school continued for many years in the same condition, all the time quartered at Tegel and still common to the officers of the field and foot artillery; these two branches of the artillery, separated in 1872, saw the last bond which united them broken in 1887. The school did not come out of its chrysalis however until the year 1889, at the time of the application of the law of the septennat voted in 1887.

Period from 1889 to 1896.—The year 1889 is a memorable one for the German field artillery; increased considerably it was now placed under authority of the army corps commanders. The artillery school, increased from one battery and a company of instruction, was divided into two schools, one a school for field artillery and the other for foot artillery whose distinct organizations were definitely regulated by a cabinet order bearing the date of 20th February, 1890.

Moreover the two schools were transferred to a larger practice field for firing, to Jüterbogk.

The new methods of fire, which had been experimented with for more than six years, were adopted and published at the same time as the new regulations for the instruction of fire in the field artillery.

In 1892, the courses which the young field artillery officers were going to take in the mixed school of artillery and engineering at Charlottenburg were suspended and replaced by a four months practical course at Jüterbogk.

From 1870, the general current of opinion was opposed to artillery officers becoming specialists. They had formerly so taken the manner of scientific augurs that a spirit of reaction set in of which Prince Hohenlohe Inglefingen gives us an idea in his seventh letter on artillery.

While speaking of artillery-men of former times he says: "The artillery man of that time was pleased to envelope himself in mystery, to have a profoundly knowing way, and if by these airs he separated himself from the other branches of the service, they contributed on the other hand to give him in comparison with these branches a certain respect which inspired them with that science which they did not share.

"As for the young artillery-man, when he had raised the veil and found out that there was not so much after all hidden beneath, he refused to believe, and did as the youth who tore the veil from the statue in the temple of Sais and of whom the poet says: 'What he saw there, what he discovered, never will he tell'; he took a certain pleasure in passing in comparison with his comrades in the other branches as a member of the scientific branch, as a superior being."

While speaking of the science necessary to the artillery officer of to-day, he expresses himself thus:

"No doubt the service is a little more complicated for the artillery officer, because he is obliged to understand harnessing, to know something about rolling stock, the care of horses and the management of carriages.

"But these do not require a scientific knowledge; it is not learned in books, it is learned only by practice. It is in drilling that skill and the wished for knowledge is acquired. But in regard to the amount of practical exercise and technical knowledge (a term which I prefer to that of 'science') that the officers of all branches require, I do not believe that either of the other two branches are inferior in this respect to the artillery."

Due to the views of Prince Hohenlohe and a great many others, from 1872 there was no longer a scientific course at Charlottenburg for field artillery officers, no longer a first year, no longer a select course (2d year) or a special mathematical course (3d year). The second lieutenants instead of going out of the war school with a provisional brevet and of being provided with a definite brevet, only after having served nineteen months with their regiment and satisfactorily passing the examination, on finishing at Charlottenburg received the definite brevet immediately, like the officers of the infantry and cavalry.

They followed only a practical course of four months at the field artillery school of fire, where the troops of instruction had been increased to three batteries and the number of professors to ten officers in place of four.

This was the last stage in the assimilation of the field artillery to the other combatant arms. Separated in 1872 and in 1887 from the foot artillery, put in 1889 under the authority of the commanders of army corps, the field artillery, after having had in 1890 its distinctive fire school, saw in 1892 its officers recruited in exactly the same way as those of the infantry and cavalry.

The course of the mixed school of artillery and engineering of Charlottenburg was no longer followed except by the foot artillery officers.

Has this radical measure, a sort of reaction, given the results that were expected?

We do not know how to answer this question, but we do know that without any warning and by means of a simple paragraph in the 1896–1897 budget, the courses suppressed at Charlottenburg for hardly four years, are, *as an experiment*, actually re-established, the first course for thirty officers the higher course for twenty; the officers who take these courses are, however, permitted to take four months at Jüterbogk, this period coming in between the two years of the course at Charlottenburg.

Returning to our history, we notice that in 1892 there were 260 field artillery officers at Jüterbogk, while in 1891 there were only 147.

In 1893 the number of troops at Jüterbogk is again increased, this time to two groups of three batteries, and to one battalion composed of three companies of foot artillery.

The two artillery practice schools are thus endowed, from this time with complete tactical units, permitting them to combine the tactical questions with the questions of firing.

Each year the number of officers who go to Jüterbogk is increased.

The field officers who since 1892 have taken a course of four weeks, must, commencing in 1893, stay six weeks at Jüterbogk. From the same year, 1893, a certain number of artillery officers of the Beurlaubtenstand have taken their period of instruction at Jüterbogk.

Strictly speaking the school of field artillery fire is regulated by the order of October 14, 1893, modified in 1894. From

October 1 to May 31, the following officers attended at different times: 20 field officers (two courses of six weeks), 144 older officers (two courses of four months), 160 second lieutenants (two courses of four months) and 144 officers of the Beurlaubtenstand (four courses of six weeks), a total of 468 officers in eight months.

There is no course from June 1st to October 1st, the range at Jüterbogk being utilized during that period for the field artillery firing of the 3rd and 4th corps, and that of the foot artillery of the guard and of the 4th and 6th corps.

The organization and management of the school of fire of the foot artillery are regulated by the orders of July 28, 1894. Different courses take place from October 1st to June 5th inclusive; 15 superior officers (one course of four weeks), 55 older officers (two courses of four months) and 33 officers of the Beurlaubtenstand (one course of six weeks).

Last year a course of four weeks was made, as an experiment, in this school for the young officers of the foot artillery from the mixed school of artillery and engineering of Charlottenburg; this year the course was permanently established.

Thirty-six non-commissioned officers go annually (18 each course) to the fire school of the foot artillery, in order to learn the drill and prepare themselves for the future duties of battery commander.

This ends the somewhat dry history of the development of the artillery practice schools at Jüterbogk.

In conclusion a few words might be said of the regulations and rules relative to field artillery fire which have been published in Germany since 1892.

On June 1, 1893, appeared a project containing rules for the practice firing and the grand maneuvers. In that same year a new manual of fire was also published; since modified by various pamphlets the last of which bears the date of February, 1896, it is still in force to-day. According to this manual the Germans employ shells with a time fuze as soon as possible; to do this they obtain with two shells with percussion fuzes a very large fourchette including the target, a fourchette of which they do not even verify the limits, preferring to sometimes being deceived than to lose time, they then pass immediately to shells with a time fuze. They do not seek a more definite range except for the high explosive shell.

Finally on February 8, 1894, a ministerial order appeared on the arrangement of the targets for the practice firing, giving in detail the silhouettes and objectives to be employed as well as the best way to proceed in order to imitate the fire of the enemy and the bursting of the projectiles.

We see from the proceeding remarks, that the Germans attach more and more importance to the fire instruction of their artillery. In their schools at Jüterbogk, they do not separate the fire instruction given to the artillery, from the tactical employment of the battery, and that is why these schools are granted independent tactical units ; two groups of field batteries[*] and a batallion of foot artillery, units which are always filled and always in readiness to march, for the discharged men are replaced, not by recruits, but by instructed men coming from artillery regiments.[†] The German do not think it sufficient for the artillery to know how to apply such and such a rule of the fire manual without a mistake, but they must also know how to suit the fire to movement and maneuvre and be able to quickly discern whether or not this fire is suitable to the tactical problem presented.

The drill plain of Jüterbogk,[‡] given over exclusively during 8 months of the year to the artillery practice schools is immense ; it is 9 kilometers long by 4 kilometers wide ; 600 officers come here annually to practice firing, drilling and maneuvring as in war.

Every artillery officer comes here three times during his career.[§]

The German artillery officer is well drilled in the firing of the battery, and also in group firing, which, introduced in the German army in 1883, is to-day eagerly practiced in the fire schools, in the annual artillery firings and in the firings executed on varied ground.

We do not believe that the Germans have had firings with great masses, notwithstanding they are the leaders in matters of artillery, for they do not appear to have collected on their fields more than two regiments at once.[||]

[Translated by Second Lieutenant J. C. GILMORE, JR., 4th Artillery.]

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[*] These two groupes of field batteries include 552 gunners and 228 drivers.

[†] One half of the discharged men are replaced on June 5th and the other half June 13th.

[‡] The artillery firing field at Jüterbogk was changed into a great drill plain in 1891.
Lately the artillery annex, which was installed there and which was a dependency of Spandau, has been transformed into an independent artillery depot. The annuity of 93256 francs allowed for 2 years and which is to continue until 1901-1902 is always employed in assisting the railroad from Berlin to Jüterbogk.

[§]

Grades.	Artillery.	
	Field.	Foot.
As 2nd Lieutenant	4 months.	1 month.
As 1st Lieutenant or Captain	4 ,,	4 months.
As a field officer	1½ ,,	1 month.

[||] The Italians united 3 regiments at Spilembergo and the Russians assembled 44 batteries at Krasnoe-selo.

AN EXPERIMENT WITH THE MILITIA IN HEAVY ARTILLERY WORK.

(Concluded.)

Suggestions for the reorganization of the nine regiments of infantry, M.V.M., and for the organization of a corps of Coast Defense Reserves, M.V.M.

1. The First Regiment of Infantry, M.V.M., to be relieved from further duty in connection with heavy artillery, and to resume its normal work in the First Brigade as infantry.*

COMMENTS.

The First Regiment of Infantry, as one of the old Massachusetts infantry organizations, has such a long and honorable history behind it that it ought not to be discontinued or in any way changed, as it would be by a permanent assignment of the regiment to heavy artillery work or by changing, as proposed, the designation of the regiment to "heavy artillery." Nor is it necessary to do this in order to provide a body of troops to act as a *reserve* to the regular troops, in defending the coast against a naval attack. Therefore the regiment should fall back to its original and normal work.

2. A special body of coast defense troops to be organized by Act of the Legislature to be known as "*The Massachusetts Corps of Coast Defense Reserves.*" This corps to take up the work of coast defense throughout all its branches, except the mobile defence assigned to the naval arm of the service.

COMMENTS.

The coast of Massachusetts is, perhaps, more exposed to naval attack in case of war with a maritime power, than any other of the United States. Especially is this true if England be considered as a possible enemy, since the Nova Scotian or New Brunswick ports are only about one full day's steaming distant. In case of war with a naval power the coast attack might fall within a few days or hours after the commencement of hostilities. There will, therefore, be absolutely no time for preparation. Everything in the nature of defense should be thought out and provided for ahead, during the quiet of peace. Hand in hand with this consideration goes that, that no branch of the service requires more careful and long continued training, than those associated with fighting efficiently the elaborate and varied armament now being provided by the general government for our coast posts. Associated with this is the further consideration that Congress will not probably consent to an increase of the United States Artillery force, sufficient to give Massachusetts an adequate defense of its coasts. It is certain that unless the Commonwealth makes provision for a force to reënforce the small regular force, that the defense provided instead of becoming a factor of safety will become an additional cause for alarm, since the guns mounted may be suddenly captured by an enterprising enemy and turned against the city and harbor. It is proposed, therefore, that just as the Commonwealth has provided by wise laws a naval reserve for the mobile defense, and just as she was the first of the states to see the wisdom of providing such a force, so, now, in regard to the shore defense she will become the pioneer and provide a land reserve, a body of troops organized and trained with the chief object of rendering an immediate and efficient reenforcement to the United States Artillery troops, stationed in the posts along the coast. It is generally agreed that troops organized for coast defense should be given a *corps* organization rather than a regimental organization. Among other reasons for this it may be said the fighting unit in coast defense is the fort's garrison, and this varies with the armament of the fort; the size of the garrison is in no relation whatever to the regimental unit, and if the regimental unit were used it would degenerate, for all coast defense purposes, into a misleading paper designation. The corps for purposes of service in connection with riot and other state police duty would be partly drilled as infantry, and for these drills it would be divided temporarily into battalions, but for all artillery purposes and coast defense work there need be no unit greater than a battery—the officers and men required to fight one group of guns. It is therefore strongly urged that the body be given the *corps* organization. This organization admits, also, of greater elasticity in assignment of garrisons to forts and in expansion in time of war.

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* The regiment had been serving one year as infantry and the next as artillery; a condition most unsatisfactory to all concerned.

3. *The Massachusetts Corps of Coast Defense Reserves* to have its personnel supplied, in the first instance, by drawing from the First Regiment of Infantry such officers and men as may volunteer to be transferred. After this class has been exhausted further appointments and enlistments to be made as now provided by law for the Naval Reserves.

COMMENTS.

It seems entirely fitting that those officers and men of the First

Regiment of Infantry who have given about a year's study to the subject of coast artillery and its use in coast defense, who have formed a liking for this class of work and who have acquitted themselves so creditably at Fort Warren during the week of field duty, August 1 to August 8, should be permitted of their own volition to transfer to the new corps. This arrangement would rectify at once the difficulty now existing in the First Regiment resulting from the fact that some officers and men like the heavy artillery service and would like to continue it, whereas others like infantry work and prefer going back to that work; the latter would remain in the First Regimet and vacancies arising in the regiment by the transfer of the former to the Coast Defence Reserves would be filled by the operation of existing laws.

4. Applications for transfer from the First Regiment of Infantry to Massachusetts Coast Defense Reserves to be made through military channels, individually, by officers and men, to the adjutant general.

COMMENTS.

This is necessary as a matter of record, and to place the direction of the organization of the new corps entirely in the hands of the highest military officer of the Commonwealth after the Governor.

5. *The Massachusetts Corps of Coast Defense Reserves* to have the following organization:

One colonel, commanding officer of the corps; 2 aids, with rank of first lieutenant.

One corps adjutant, with the rank of captain; 1 corps quartermaster, with rank of captain; 1 paymaster with the rank of captain; 1 range officer with rank of captain; 1 ordnance officer with rank of captain; 1 torpedo officer with rank of captain; 1 signal officer with rank of captain.

One surgeon with rank of major; 2 assistant surgeons with rank of captain.

One corps sergeant major; 1 corps quartermaster sergeant; 1 paymaster sergeant; 1 range sergeant; 1 ordnance sergeant; 1 torpedo sergeant; 1 signal sergeant; 1 chief trumpeter; 1 hospital steward; 2 assistant hospital stewards.

One lieutenant-colonel; 2 majors; 8 batteries.

Each battery to be organized as follows:

One captain; 1 first lieutenant; 1 second lieutenant; 1 first sergeant; 4 sergeants; 8 corporals; 32 first class privates; 32 second class privates; 2 trumpeters; 1 machinist with rank of sergeant; 1 electrician with rank of sergeant; 1 armorer with rank of sergeant.

In time of emergency the Governor to be authorized to add to the above battery organization not to exceed 2 second lieutenants, 8 sergeants, 16 corporals, 1 machinist and 64 privates of the first class and 64 privates of the second class. In time of war, with the consent of the legislature, the Governor to be authorized to add to the corps not to exceed 4 majors and 16 batteries.

This provides a *personnel* fitted in all details to take up and carry to the highest point of proficiency the work of coast defense in all its divisions. It provides for the command, administration, supply, instruction and employment in action of the troops.

In order to show in a more definite way how this force would be employed in time of war, let us suppose that Boston Harbor is threatened with a naval attack, that the corps has been called into the service of the United States as provided in the Constitution of the United States and laws based thereon, and that it has been ordered to one of the harbor forts to man the armament provided by the United States for the defense of the harbor.

Without taking any special fort, we may assume one that has a complete armament of large-caliber rapid-fire and machine guns, with such auxiliary services and accessories as may be required to give an effective modern defense; in short, let us assume a set of typical defensive conditions and place the personnel of the corps in connection therewith. Let the armament be as follows:

ARMAMENT.

Four 12-inch rifled guns; four 10-inch rifled guns; eight 4-inch rapid fire guns; four small-caliber machine guns; thirty-six fixed torpedoes; four patrol launches; four search lights; one pneumatic torpedo gun; range and position finders.

Every element of defense here named would probably be found in any modern sea-coast fort. The large caliber guns are required to perforate the heavy water line and turret armor of battleships; the 4-inch rapid fire guns to attack the unarmored parts of warships; the machine guns to reply to machine gun fire stationed aloft in the military masts of war vessels, to sweep the decks and repel landing parties; the fixed torpedoes to make navigable water areas dangerous and to compel the enemy to anchor or reduce speed; the patrol launches to patrol the torpedo fields and adjacent waters at night and in thick weather, to defend the torpedo fields against small boat interference and to give the alarm in case of threatened attack; the search lights to light up the entire field of fire, in case of a night attack by the ships or by a landing party; the pneumatic gun gives a form of attack that is most demoralizing to a naval enemy, and will probably be employed in many of our forts; the range and position finding service is that on which the accuracy of fire of all the weapons hangs, although named last, it is the very breath of life of all. In an action between the fort and warships all the elements of defense here specified would be in use *at the same time*, and the personnel assigned to the service of such an armament should be able to put all into efficient operation instantly, day or night, and to maintain all continuously in service during several hours, at least. That is, there should be at least *two reliefs* complete throughout, especially where great physical exertion or mental strain is involved.

Referring now to the list of officers and men given above, the *colonel*, with aides, will be in command of all the troops in action, as indicated above. The *lieutenant-colonel* would relieve or assist him when required. The *corps adjutant* would be charged with the customary paper and routine work of an adjutant, pertaining to records, details, orders and ceremonial duty. The *corps quartermaster* would be charged with the customary details connected with the supply of the *personal* needs of officers and men. The *paymaster** would be charged with payments and the pay records. The *range officer* is a new position and requires, perhaps, some explanation. The importance of the range and position finding service has been referred to. It is so important and requires such constant and intelligent attention to maintain it in perfect condition and to work it rapidly in action, that its direction should be placed under an officer of much experience and ability. The range officer would be charged with everything connected with the field of fire, including the patrol boats, but not the fixed torpedoes. He would be responsible that the range and position finding lines and apparatus are always in perfect working order, and that in time of action the targets selected by the commanding officer to be fired at are accurately and continuously plotted, and the information immediately conveyed to the commanding officer and to the guns. The *range officer* should, if possible, be a person possessing some electrical information as to the use, adjustment and repairs of ordinary electric lines, and have some knowledge of mathematical angle measuring instruments and their use in the solution of simple triangles. A civil engineer graduate of any of our institutes of technology or universities would meet perfectly the requirements of the position. The *ordnance officer* would be charged with maintaining in working order all machinery connected with the supply of ammunition to the guns and with the gun carriages, in addition to the customary duties of an ordnance officer in attending to the care, preservation storage and supply of all ordnance and ordnance stores. For this duty the *ordnance officer* should, if possible, be an experienced mechanial engineer. The *torpedo officer* would be charged with the torpedo defense in all its parts. He would attend to the laying of the torpedo cables, the planting of the torpedoes, the testing of the lines and the firing of the torpedoes in action. The officer should be one familiar with high explosives, the handling of them and care of them. The *signal officer* would be charged with the care and repair of all electric lines of communication, of the electric light and motor lines, and all instruments used in connection with these lines, in addition to the customary duties connected with flag, heliograph and telegraphic signaling. He should be one familiar with practical electrics, an electrical engineer if possible. The *surgeon* and *assistant surgeons* would have the customary duties of military surgeons to perform.

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* Each regiment and separate organization of the M.V.M. has its paymaster.

Each staff offcer referred to will require a non-commissioned subordinate to assist him in the discharge of his duties; this explanation covers the whole list of the *non-commissioned staff* from sergeant major to assistant hospital stewards, except the *chief trumpeter;* the latter will be required to give instruction to the trumpeters of the corps and to lead in the trumpet calls, etc.

Two majors are provided so that there may be commanders for bodies larger than a single battery, when such might be required, and for the command of detached works or forts about the harbor; and also for the command of infantry battalions when required to appear in that formation, the eight batteries permitting the formation of two battalions of four batteries each. The organization of the battery is the customary one and requires no special comment, except as to the *machinist, electrician* and *armorer.* These grades are considered necessary now for all heavy artillery troops. The *machinist* will be required at the guns in action, and at other times to make repairs to the machinery of the carriages or to the mechanical appliances used in connection with the guns. The *electrician* to repair telegraph and telephone lines and instruments, and electrical apparatus generally. The *armorer* to make repairs to breech mechanism of guns, to repair small caliber guns, and, generally, to do such gun-smith work as may be necessary and possible at a sea-coast fort.

The *sixty-four privates* of each battery are to be equally divided into "first class" and "second class" privates, as now provided for enlisted men of the engineer battalion, U.S.A. This system enables a battery commander to transfer a private from the lower to the higher class on coming up to a certain standard of instruction and drill, and to retransfer to the lower class if the standard be not continued; it is a strong lever for attaining high efficiency in a command.

The *personnel* as laid down includes on peace footing 40 officers and 667 enlisted men. The scheme provides further for an increase of this in time of emergency, at once, by the action of the Governor, to a fighting *force of over 1800 enlisted men without increase of officers*, except the addition of two second lieutenants to each battery. It provides, furthermore, in time of war, for an increase of the force to *nearly 6000 combatants* without further increase in the list of officers of the Corps staff, by the addition of six majors and sixteen batteries, a force ample enough to man the entire armament planned for the defense of Boston Harbor.

It is believed that this great elasticity of the proposed organization will commend itself. By providing a permanent highly trained scientific corps itself, and by providing for the continual training of eight batteries in time of peace, a nucleus of trained gunners is produced, around which the greater number can readily crystallize, and the new men be instructed with least possible delay at the outbreak of war.

The employment of the corps in connection with the service of the armament assumed above, may be considered more in detail, as follows:

The service of a large caliber gun, involves the handling of projectiles weighing several hundred pounds, and of powder charges weighing from one-half to one-third as much as the projectiles. It may be divided into two parts: first, the loading, laying and firing of the gun; second, the supply of ammunition.

SERVICE OF LARGE-CALIBER RIFLED GUNS.

For one Gun.

One lieutenant in general charge of service in all its parts.

Gun Detachment.

One sergeant in charge of laying and firing; one corporal in charge of loading; two privates to give elevation and two privates to give direction at moving targets, these must be done at the same time; four privates to handle projectile, insert it and push it home; two privates to handle powder charge, insert it and push it home; three privates, supernumeraries.

Projectile Detachment.

One sergeant in charge of preparation and transportation of projectiles from main supply to the gun; one corporal at main supply in charge of preparation of projectiles; four privates at main supply to handle projectiles; twelve privates in two squads of six each, to carry projectiles from main supply to the gun; four privates, supernumeraries.

Powder Detachment.

One sergeant in charge of preparation of cartridges and transportation to the gun; one corporal in magazine supervising preparation of cartridges; six privates in two squads of three each to carry cartridges from the magazine to the gun; two privates, supernumeraries.

Total for one complete service detachment: 1 lieutenant, 3 sergeants, 3 corporals and 43 privates.

For two reliefs: 2 lieutenants, 6 sergeants, 6 corporals, 86 privates.

That is, allowing for the customary detachments, guard details, etc., it will require the full complement of one battery on war footing to serve *two* large caliber rifled guns, viz: 1 captain, 4 lieutenants, 12 sergeants, 12 corporals, 172 privates.

The eight large caliber guns of the assumed ornament, would therefore require for their efficient service: 4 captains, 16 lieutenants, 48 sergeants, 48 corporals, 688 privates.

SERVICE OF RAPID FIRE GUNS.

For a single gun it will require: one sergeant to supervise service of piece; one corporal to load, lay and fire the piece; two privates to handle powder charges; four privates in two squads of two each, to handle and transport projectiles from main supply to gun; one private, supernumerary.

One lieutenant would be in command of four gun detachments.

Thus for the rapid fire guns there would be required: 1 captain in command of battery, 2 lieutenants, 8 sergeants, 8 corporals, 48 privates.

For the second relief it would be necessary only to change the corporals and privates. Thus for two reliefs there would be required: 1 captain, 2 lieutenants, 8 sergeants, 16 corporals, 96 privates.

That is practically one battery would be required to serve the eight guns named in the list.

SERVICE OF MACHINE GUNS.

The service of one Gatling gun requires: One sergeant to supervise entire service of piece; one corporal to load, lay and fire the piece; two privates to supply cartridges and feed them to the gun; one private, supernumerary.

One lieutenant would be in charge of two guns.

Thus the four machine guns of the list would require: 1 captain in charge and director of machine gun fire, 2 lieutenants, 4 sergeants, 2 corporals, 12 privates; and for two reliefs, changing only corporals and privates: 1 captain, 2 lieutenants, 4 sergeants 8 corporals, 24 privates.

SERVICE OF PNEUMATIC GUN.

One lieutenant in charge of entire service; one sergeant in charge of loading, laying and firing; one corporal in charge of projectile supply; twelve privates in two squads of six each, to handle and insert projectiles; one machinist in charge of air pumping apparatus; two privates, assistants at air-pump; two privates, supernumerary.

For two reliefs there would be required: 2 lieutenants, 2 sergeants, 2 corporals, 2 machinists, 32 privates.

The machine guns and pneumatic gun would be assigned to one battery.

TORPEDO SERVICE.

This is under the general direction of the torpedo officer. Associated with it will be required: 1 torpedo sergeant, assistant; 2 sergeants; 2 corporals and 8 privates detailed from batteries.

For complete service with two reliefs: 1 torpedo officer, 1 torpedo sergeant, 4 sergeants; 4 corporals and 16 privates detailed from batteries.

PATROL LAUNCH SERVICE.

This is under the general direction of the range officer assisted as follows: Four sergeants, one in charge of each boat; four corporals, acting coxswains; eight privates, two on each boat as crew; four machinists, one on each boat in charge of engine (if the motor be electric then four electricians instead of four machinists).

For two reliefs there would be required: 8 sergeants, 8 corporals, 16 privates and 8 machinists detailed from the batteries.

SEARCH LIGHT SERVICE.

This is under the general charge and direction of the signal officer and the signal sergeant. They would be assisted by the following detail from the batteries: Four sergeants in charge of each light; one machinist in dynamo room; one electrician in dynamo room; one electrician linesman; two privates, general assistants; one private, supernumerary.

And for two reliefs: 8 sergeants, 2 machinists, 4 electricians and 6 privates detailed from batteries.

RANGE AND POSITION FINDING SERVICE.

This is under the general charge and direction of the range officer and the range sergeant. They would be assisted by the following detail from the batteries: two lieutenants, observers at ends of base line; one lieutenant, plotting and predicting officer, at the plotting board; two corporals, one with each observer; two privates, one with each observer; two corporals at the plotting board; two privates at the plotting board; two electricians to keep lines and instruments in working order; four privates to assist electricians; three privates, supernumerary.

For two reliefs: 6 lieutenants, 8 corporals, 22 privates and four electricians detailed from the batteries.

The service of the armament as here given requires, therefore, besides the staff and non-commissioned staff officers the following: 6 captains, 28 lieutenants, 82 sergeants, 94 corporals, 12 machinists, 8 electricians and 900 privates.

On a war footing the strength of the eight batteries would be: 8 captains, 32 lieutenants, 96 sergeants, 192 corporals, 16 machinists, 8 electricians and 1532 privates.

Subtracting the former numbers from the latter, we have the following as the number not actually engaged in the service of the armament: 2 captains, 4 lieutenants, 14 sergeants, 98 corporals, 4 machinists and 632 privates.

From these must be deducted the guard and those absent from sickness and other causes.

There would remain a force equivalent to about four small companies, with a complement of officers and non-commissioned officers, which, under the command of the lieutenant-colonel or one of the majors, would be formed as a battalion and held in readiness during the action to make good casualties, if they should be greater than allowed for in the supernumeraries above, or to repel a landing force should an attack of this nature be attempted.

From this brief analysis of the organization suggested, it appears that a body of troops would be provided thereby, just adequate for an efficient defense of a typical modern sea-coast fort against an attack of armor clad battleships; that it would possess all the features requisite for highly scientific training in time of peace; that it could at once, without strain, be increased to a force having three times the fighting strength of the peace footing by the action of the Governor alone, were an emergency to arise, and that in case of threatened war the corps could still further be increased by the Legislature, by the addition of other batteries, without increasing the staff or non-commissioned staff, giving a force large enough for the defense of all forts planned for Boston Harbor.

Respectfully submitted,

E. M. Weaver,

1st Lieutenant, 2nd Artillery.

HEADQUARTERS FIRST REGIMENT OF INFANTRY.

First Brigade, M. V. M.

South Armory, Boston, October 26th, 1896.

Lieutenant James A. Frye,
Adjutant First Infantry.

Sir:

I have the honor to make report of the gun practice of the First Infantry, at Fort Warren during the week of August 3rd to 8th, 1896, inclusive.

According to schedule in Regimental Circular No. 1, C. S., firing commenced at 2:00 p. m., Tuesday, August 4th, and continued through the three following days; the last shot being fired at 7:15 p. m., Friday, August 7th.

It was arranged to finish by noon Friday, but many vexatious delays allowed of but five companies firing up to Friday morning, leaving thirty-five shots to be fired that day.

The conditions during the week were decidedly adverse to good shooting, an intermittant fog shutting out the target, and only at intervals could the target be simultaneously found from the gun and stations "A" and "B."

The target had been previously anchored some 3,600 yards distant between Broad Sound and the Brewster Islands. This went adrift on Wednesday, and no facilities having been provided to place a new one, further firing was prevented. The government tug *Resolute* kindly agreed to take out the new one, but the fog shut in so thick the Captain considered it unsafe to risk his deep draught boat in such shallow waters. It was subsequently taken out on Thursday by a boats crew of regulars, but in the fog was anchored at a somewhat shorter range.

During the lifting of the fog, almost invariably good shots were made, and had the conditions been the same throughout, a much better showing would have been made. It would frequently happen that while the target was clear from the Home Station, the ricochet splash would be the only one seen from one of the angle stations, giving the records of some companies at the plotting board a much wider deviation than actually made. I enclose the record of "mean absolute deviation" and number of hits in the vertical plane.

I respectfully recommend that in future gun practice, if results commensurate with the expense incurred are to be obtained, there should be a tug or light draught launch placed under the absolute control of the range officer; that during all firings it should be stationed behind Lovell's Island, with a signal squad aboard to keep in immediate touch with the range officer, for the purpose of warning off vessels which might work in dangerously near the target, and to be ready *at once* to replace a target in case of drift or hit.

There should be provided a complete set of signal flags. The signaling for the last two years has been done by members of the regiment with their own flags; they have given a great amount of extra time to the study, it requiring out of door practice, necessarily during business hours, to perfect themselves. A Signal Corps is an absolute necessity, and a complete kit should be provided the regiment at once.

I would also suggest that at the next practice, a frame target be used, the keg and flag target being too indistinct at two miles distance.

I am, very respectfully, your obedient servant,
(Signed) Charles L. Hovey,
Lieutenant-Colonel, First Infantry.

HEADQUARTERS FIRST REGIMENT OF INFANTRY.

First Brigade, M. V. M.
South Armory, Boston, November 17, 1896.

Major-General Samuel Dalton,
Adjutant-General, State of Massachusetts.

General:

In accordance with General Orders No. 9, A. G. O., current series, the First Regiment of Infantry performed its six days state duty (five days regular camp duty and fall field day) at Fort Warren, Boston Harbor, August 3rd to 8th inclusive. Nine companies of the regiment, A, B, C, D, G, H, I, K, and L, commenced their tour of duty Saturday, August 1st; three companies, E, F, and M, Sunday, August 2nd, all giving an extra days duty to the state without pay, but at an added expense to the regiment of over $1000. The regiment was transported by the Peoples Line of steamers to and from Fort Warren in a most satisfactory manner without accident or delay. The first day in camp, Sunday, was utilized in straightening quarters and arranging details for the week's duty, the hours of which were in accordance with General Orders No. 17 from Regimental Headquarters as follows:

First call	5.50 a. m.
Reveille, roll-call and setting-up drill	6.00 a. m.
Fatigue call, police entire camp	6.15 a. m.
Breakfast call	6.30 a. m.
Surgeon's call	7.00 a. m.
Officers' call	7.10 a. m.
First Sergeants' call	7.15 a. m.

Drill call, commencement of morning schedule	7.30 a. m.
First call, guard mounting	8.40 a. m.
Adjutant's call, guard mounting	9.00 a. m.
Inspection quarters	9.30 a. m.
Recall, end of morning schedule	12.00 m.
Dinner call	12.30 p. m.
Drill call, commencement of afternoon schedule	2.00 p. m.
Recall, end of afternoon schedule	5.00 p. m.
First call, evening parade	5.30 p. m.
Assembly, evening parade	5.40 p. m.
Adjutant's call, avening parade	5.45 p. m.
Supper call	6.30 p. m.
Tattoo, roll-call	9.00 p. m.
Call to quarters	10.45 p. m.
Taps	11.00 p. m.

This routine was strictly followed during the week, the regiment having the active assistance, advice and hearty co-operation of Lieutenant-Colonel Carle A. Woodruff, Commandant of the Post, and the officers and non-commissioned officers of the garrison. The good effect of the series of lectures delivered to the officers of the regiment by Lieutenant E. M. Weaver, 2nd Artillery, U. S. A., and the practical drill and instruction in the armory in heavy artillery by the companies of the regiment, during the winter months was made apparent by the aptitude with which the duty as prescribed in Circulars Nos. 1 and 2, from these headquarters was carried out. Officers, non-commissioned officers and men seemed to have an intelligent comprehension of what was required and expected of them and went at it with a hearty enthusiasm that in itself was a guarantee of rapid progress in the work for which they had been specially detailed. The companies of the regiment were formed and designated as batteries[*],—a friendly rivalry was quickly engendered as to which would perform its prescribed duty in the most expeditious and soldierly manner, the result being that rapid progress and improvement was noted from day to day, particularly in "mechanical maneuvers" and "mechanical appliances." Target practice with the 8-inch rifle was had by each battery of the regiment under the immediate supervision of Lieutenant-Colonel C. L. Hovey. The general result of the firing was in the main satisfactory; much delay was caused by the drifting of the target, the lack of facilities for replacing it causing a loss of valuable time. Batteries were divided in gun detachments and were in sole charge of and instructed by a non-commissioned officer, under the direct supervision of the battery officers. This system worked admirably, as under it the individuality of the non-commissioned officers of the regiment was developed and brought to the front; the responsibility of their duties causing them to appreciate the dignity and authority of the positions as never before; with the attendent result of improved discipline throughout the organization from the example and added authority of the non-commissioned officers. The daily inspection of drill and instruction was under the majors of battalions, a report of the day's work was made by them to the Commanding Officer. Little attention (from lack of time) was given to infantry drill. Discipline of the command was good, only one case of unsoldierly conduct coming under the observation of the Commanding Officer. The food furnished by Caterer Valaquet to the entire command was uniformly good in quantity and quality and reasonable in price. The attendance during the entire week was very satisfactory, out of a total enrollment of 782, there was present during the entire six days duty an average of 753 officers and men, being $96\frac{3}{10}$% of the regiment's enrollment, this in itself is a record that every officer and man contributing to the result has reason to be proud of. Camp was broken Saturday, August 8th, the regiment arriving in Boston at 10.30 a. m.; a street parade was had through the business portion of the city, the command was dismissed at 12.00 m., this ending one of the most satisfactory tours of duty, in the opinion of the Commanding Officer, the regiment has performed since his connection with it. With this successful tour of duty fresh in mind, together with the aroused interest of officers and men in the study of heavy artillery, it suggests itself very strongly to the colonel commanding that the time has now arrived when a well defined policy relative to the future course of instruction of the regiment in heavy artillery should be formulated. Considering the limited time officers and men under the most favorable conditions can give to military study and drill, it would seem wise to have them devote all their energies to the study of heavy artillery. It is not possible under the conditions that necessarily prevail in the militia for officers and men of the state force ever to acquire that thorough knowledge of modern military science that obtains in the artillery arm of regular service; time, opportunity and lack of equipment preventing. In the present changed and ever changing condition of modern warfare, with the defenseless condition of our sea coast, both in fortification, armament and garrison; with the commercial center of our state at the mercy of an enemy's fleet ever in mind; it would seem as though the time had arrived when all sea-board states should not depend solely on the United States government for protection in case of need, but place themselves in a position to protect in some degree the vital commercial interest of their vulnerable sea-board frontier. With this in view, I would respectfully suggest that the First Regiment of Infantry be changed by an ammendment of the present militia law, to a heavy artillery regiment, for coast defense, equipped, uniformed and instructed as such. If this change can be made, I feel with the present and increasing interest in the study of heavy artillery the regiment I now command could in a short time be made efficient as an artillery organization, qualified to garrison the defenses of Boston Harbor should such a necessity arise.

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[*] This was done in February, and from February to August all formations for drills and ceremonies were as prescribed in "Marching Maneuvers," Tidball's Manual, pages 5 to 34. E. M. W.

In closing this report I desire to express the great personal obligation I am under to Lieutenant-Colonel C. A. Woodruff, Lieutenant E. M. Weaver and all the officers stationed at Fort Warren for their advice, counsel and assistance; a large measure of the success of this tour of duty is owing to their hearty co-operation.

Very respectfully, your obedient servant,
Thomas R. Mathews,
Colonel First Regiment of Infantry.

[1st Lieutenant E. M. Weaver, 2nd Artillery.]

REPORT ON DEVELOPMENT OF A PHOTO-RETARDOGRAPH AND ITS APPLICATION TO THE DYNAMIC MEASUREMENT OF RESISTANCE TO COMPRESSION OFFERED BY THE COPPER CYLINDERS USED IN CRUSHER GAUGES.

By First Lieutenant B. W. DUNN, Ordnance Department, U.S. Army.

Reprinted from Notes on the Construction of Ordnance, No. 71, by authority of Chief of Ordnance, U.S. Army.

CONCLUDED.

2. *Resistance Curves as Modified by Graphical Adjustment.*—The broken curve, Plate VI, shows the measured velocities of piston, or rate of compression, as a function of time. The full curve shows the assumed true rate of compression. In constructing this curve we have the initial ordinate and initial tanget from known height of fall, and, with these conditions imposed, the curve is made to take the mean position indicated by experimental data. The first differences of a set of ordinates of this adjusted curve, separated by the uniform interval of time Δt, gives us the successive retardations for the same interval.

The broken curve, Plate VII, shows the values of these retardations as a function of time. The full curve gives, by a second graphical adjustment, a closer approximation to true values. In constructing it, we know that it passes through the origin and is tangent to the vertical at that point. We also know that it is tangent to the horizontal when retardation reaches a maximum. With these conditions imposed, it is made to take the mean position indicated by plotted points which come from data given by Plate VI. By substituting any ordinate of this adjusted curve for d^2c in the expression $R = -\frac{M d^2c}{(\Delta t)^2}$, we obtain, neglecting W, the value of resistance R, for the corresponding time t. The ordinates are selected so that the values of t are those given in the table of compressions and times for negative No. 22, and we are thus enabled to construct for this negative the resistance curve shown by Plate VIII, where resistances appear as a function of copper compressions. For comparison, the mean static curve is introduced. Corresponding graphical adjustments were made for data from other negatives, but for sake of brevity the plates showing the graphical constructions are omitted and only the resulting curves which appear on Plate VIII are submitted.

It seems safe to say that the mean of dynamic resistance curves in Plate VIII must be a close approximation to the true curve when the time consumed in compression is between 0.003 and 0.004 second. The measured area under resistance curve No. 22 is 673 inch-pounds. The measured area under static curve is 599 inch-pounds. The energy in weight at impact was 679 inch-pounds. The close agreement to theoretical value of area under dynamic curve is principally of use as a test of accuracy of graphical construction, since the assumption of theoretical impact velocity for the adjusted velocity curve in Plate VI should cause this agreement.

The low value of area under static curve, however, is an exceedingly important corroboration of the statement based upon results of this investigation, that maximum pressures given by static tarage are too low.

From adjusted resistance curves the following data are presented in connection with data from Plates III, IV and V.

Negative.	Compression.	Resistance, dynamic.	Resistance, static.	Difference, actual.	Difference, crusher gauge.
	Inch.	Pounds.	Pounds.	Pounds.	Lbs. per sq.-in.
No. 3 . . .	.1400	3.862	3.328	534	5,340
No. 6 . . .	.1400	3.950	3.328	622	6,220
No. 22 . . .	.2060	5.087	4.605	482	4,820
No. 23 . . .	.2060	5.087	4.605	482	4,820

As a second approximation, we find that, when the time of compression is from 0.003 to 0.004 second the crusher-gauge pressures are too low by about 5000 pounds per square inch.

3. Empirical Formulae for Maximum Resistances.—Assuming copper resistances to increase directly with compressions, let $r =$ resistance at any point, $R =$ maximum resistance, $c =$ compression corresponding to r, $C =$ maximum compression, $v =$ velocity of compressing weight corresponding to c, $V =$ initial velocity of compressing weight, $M =$ mass of compressing weight, $t =$ time from impact to compression c, $T =$ time from impact to compression C.

The forces of gravity and friction being negligible as compared with r, we have

$$r = ac = -Mv\frac{dv}{dc} \quad . \quad . \quad . \quad . \; (1).$$

Integrating

$$ac^2 = -Mv^2 + C = -Mv^2 + MV^2 \quad . \; . \; . \; (2).$$

$$v^2 = V^2 - \frac{ac^2}{M} \quad . \; . \; . \; . \; (3).$$

Substituting $\frac{dt}{dc}$ for $\frac{1}{v}$ in equation (3), solved with respect to $\frac{1}{v}$,

$$dt = \frac{dc}{\sqrt{V^2 - \frac{ac^2}{M}}} \quad . \; . \; . \; . \; (4).$$

Integrating

$$t = \sqrt{\frac{M}{a}} \sin^{-1} \sqrt{\frac{a}{M}} \, \frac{c}{V} \quad . \; . \; . \; . \; (5).$$

From work performed in producing compression c, we have

$$rc = M(V^2 - v^2) \quad . \; . \; . \; . \; (6).$$

Substituting in (5) the value of a, in terms of c and v, obtained from (1) and (6), we have

$$t = \frac{c}{\sqrt{V^2 - v^2}} \sin^{-1} \sqrt{\frac{V^2 - v^2}{v}} \quad . \; . \; . \; (7).$$

If $v = 0$, then $c = C$, $t = T$, and (7) becomes

$$T = \frac{\pi}{2} \, \frac{C}{V} \quad . \; . \; . \; . \; (8).$$

Substituting for C its value, in terms of R, from relation $RC = MV^2$, we have

$$T = \frac{\pi}{2} \, \frac{MV}{R} \quad . \; . \; . \; . \; (9)$$

From theory of quantities of motion, we have, for the constant force R' acting during the time T' on mass M and generating in it the negative velocity V',

$$R' = -\frac{MV'}{T'} \quad . \; . \; . \; . \; (10).$$

The above equation (10) contains three variables, any two of which may be assumed.

If we require R and T to have values which satisfy equation (9) and determine corresponding value of V' we find

$$V' = -\frac{\pi}{2} V \quad . \; . \; . \; . \; (11).$$

Squaring both members and multiplying by $\frac{M}{2}$,

$$\frac{M V'^2}{2} = \frac{\pi^2}{4} \frac{M V^2}{2} \quad . \quad . \quad . \quad . \quad (12).$$

Representing by W and W' the amounts of work performed (1) by copper resistance over the path C, and during the time T, under the assumed law of uniform increase and (2) by the maximum resistance R (constant) during the same time T, we have from (12)

$$\frac{W'}{W} = \frac{\pi^2}{4} = 2.46744 \quad . \quad . \quad . \quad . \quad (13).$$

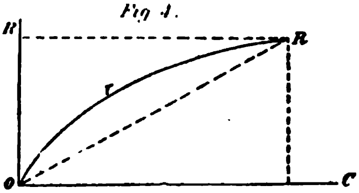
From (13) we see that, in case of uniformly increasing resistence, *the work actually done is $\frac{1}{2.4674}$ times the work that would be done in the same time by a constant force equal to the maximum resistance developed.*

If, instead of increasing uniformly, the copper resistance is constant and equal to R, the ratio given by (13) becomes

$$\frac{W'}{W} = 1 \quad . \quad . \quad . \quad . \quad (14),$$

and for any law of increase intermediate between these two, such as the curve O r R, this ratio lies between 1 and $2.4+$. When investigated as hereinafter described, our experimental data indicate that this ratio may be assumed as constant and equal to 2 when the total time of compression is between 0.003 and 0.004 second.

Fig. 4.



Under this assumption the value of R, or maximum resistance, in terms of T, the actual time of compression (measured) follows.

$$M V'^2 = 2 M V^2,$$

$$V' = \sqrt{2}\ V,$$

and equation (10), (T' being equal to T) gives

$$R = \frac{\sqrt{2}\ M V}{T} \quad . \quad . \quad . \quad . \quad (15).$$

Equation (15) is the empirical formula for maximum resistance.

The assumption that the unknown law of development of copper resistance corresponds, for the given values of T, to the ratio $\frac{W'}{W} = 2$ is based upon the following considerations:

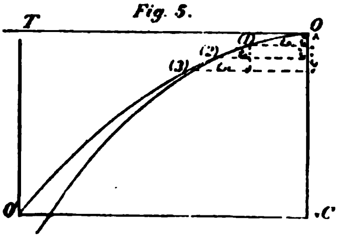
From general appearance of experimental curve (Plate II) and a more detailed study of the tabulated ordinates and abscissas it appears more than probable that the curve belongs to the parabola family.

The final sets of measured ordinates of this negative, No. 7, are given in column 1 of the following table:

Measured com-pressions.	Mean com-pressions.	Trial Parabola. $t^2 = (5.6207762-10)\,c$.		Limiting Parabola. $t^2 = (5.6006113-10)\,c$.	
		$0.16995-c'$	$\Delta c'$	$0.16995-c''$	$\Delta c''$
1	2	3	4	5	6
inch.	inch.	inch.	inch.	inch.	inch.
.16995	.169923	.16995	.00000	.16995	.00000
.16992		.16992	.00000	.16992	.00000
.16990		.16998	+ .00008	.16987	— .00003
.16983	......	.16981	— .00002	.16980	— .00003
.16974	......	.16972	— .00002	.16970	— .00004
.16965	......	.16960	— .00005	.16959	— .00006
.16955	......	.16947	— .00008	.16944	— .00011
.16940	......	.16931	— .00009	.16928	— .00012
.16918	......	.16913	— .00005	.16909	— .00009
.16899	......	.16892	— .00007	.16887	— .00012
.16872	......	.16870	— .00002	.16864	— .00008
.16847	.168223	.16849	+ .00002	.16842	— .00005
.16826		.16822	— .00004		
.16794		.16793	— .00001		
.16763	......	.16762	— .00001		
.16729	......	.16729	.00000		
.16698	......	.16693	— .00005		
.16657	......	.16655	— .00002	.16639	— .00018
.16619	......	.16615	— .00004		
.16575	......	.16573	— .00002		
.16529	......	.16528	— .00001		
.16484	......	.16481	— .00003		
.16440	.163887	.16440	.00000	.16413	— .00027
.16392		.16389	— .00003		
.16334		.16335	+ .00001		
.16276	......	.16280	+ .00004		
.16208	......	.16222	+ .00014		
.16148	......	.16162	+ .00014		
.16089	......	.16100	+ .00011	.16057	— .00032
.16034	......	.16035	+ .00001		
.15957	......	.15969	+ .00012		
.15888	......	.15900	+ .00012		
.15814	......	.15802	— .00014	.15773	— .00041

The consecutive ordinates in any set are separated by 0.00050 meter, 0.00542 meter being the equivalent of Δt. The time interval between corresponding ordinates in consecutive sets is Δt. The second column shows three mean ordinates separated by Δt.

Fig. 5.



A parabola, $t^2 = ac$, referred to axes O C and O T, whose directions only are fixed, can be made to pass through these points, and a comparison of intermediate ordinates of experimental curve and parabola for corresponding abscissas will show degree of coincidence of two curves. Representing the parabola coordinates of (1) by t_0, c_0, of (2) by $(t_0 + t')$, $(c_0 + c')$, and of (3) by $(t_0 + t'')$, $(c_0 + c'')$, we have the equations

$$t_0^2 = a\,c_0,\ (t_0 + t')^2 = a\,(c_0 + c'),\ (t_0 + t'')^2 = a\,(c_0 + c''),$$

to find t_0, c_0 and a.

We find

$$t_0 = \frac{c''\,t'^2 - c'\,t''^2}{2\,(c'\,t'' - c''\,t')},\qquad c_0 = \frac{c'\,t_0^2}{t'\,(t' + 2\,t_0)},\qquad a = \frac{t_0^2}{c_0}.$$

With the points selected as in this case, $t'' = 2\,t' = 2\,\Delta\,t$, $c' = 0.001700$ inch, $c'' = 0.006036$ inch, and we find

$$\log t_0 = 5.5314638 - 10$$
$$\log c_0 = 5.4421514 - 10$$
$$\log a = 5.6207762 - 10$$

The equation of parabola, referred to axes O C and O T, is *$t^2 = (5.6207762 - 10)\,c$, and its vertex is 0''.169923 + c_0 = 0''.169923 + 0''.000027679 = 0''.16995 + above origin of experimental curve. By calculating values of c in parabola for values of t, corresponding to measured ordinates given in column 1 (t in parabola = $T - t$ in experimental curve), and subtracting results from the constant 0''.16995 +, we obtain values in column 3; and these compared with corresponding values in column 1 (differences given in column 4), show how close parabola comes to experimental curve. By slightly raising vertex of parabola it will, evidently, be brought nearer mean curve.

In columns 5 and 6 corresponding data are given for a curve which, for reasons heretofore given, is taken as the limiting parabola. The *origin* of limiting parabola coincides with *end* of experimental curve and the two are tangent at that point. For sake of brevity no further data is given on this point; but it may be accepted as a fact that all experimental curves coincide at their vertices with parabolas as closely as shown by the table for negative No. 7. As we recede from the vertex and determine, by the method given, the equations of parabolas passing through three selected points of curves we find a gradual decrease in the values of a and an increase in values of c_0 and t_0.

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* In diagram the experimental curve is represented with origin at O'. The *origin* of parabola is near the *end* of experimental curve.

The general form of equation of experimental curve is $t^2 = xc$, a parabola with a variable latus-rectum. The experimental data submitted may assist some accomplished mathematician in determining x as a function of c or t.

From release of weight to impact the relation between time and distance passed over by falling weight is $t = \frac{2}{g} h$. After impact, c takes the place of h and the latus-rectum changes gradually from $+\frac{2}{g}$ to $-a$.

The minus sign is disregarded in the following equations, as only numerical values of R are sought.

If the equation of a parabola coinciding at its vertex with end of experimental curve be

$$t^2 = a\,c \quad \ldots\ldots (16),$$

the value of maximum resistance R (neglecting gravity) will be

$$R = M \frac{d^2 c}{d t^2} = \frac{2M}{a} \quad \ldots\ldots (17).$$

The path C_m corresponding to action of the constant force R for the measured time of compression T is obtained by substituting T for t in (16).

$$C_m \frac{T^2}{a} \quad \ldots\ldots (18).$$

The work that the constant force R is capable of performing during the time T is

$$W' = R\,C_m \quad \ldots\ldots (19).$$

By comparing values of W', thus determined for the different negatives, with the actual work performed by resistance of specimen, $W = \frac{M V^2}{2}$ the empirical value 2 for ratio $\frac{W'}{W}$ was observed to hold.

Substituting $2\,W = M V^2$ for W' and solving with respect to C_m (19) becomes

$$C_m = \frac{M V^2}{R} = \frac{T^2}{a} \quad \ldots\ldots (20).$$

Substituting value of a from (20) in (17) and reducing, we find

$$R = \frac{\sqrt{2MV}}{T} \quad . \; . \; . \; . \; (21),$$

the empirical formula heretofore given (equation (15)).

The following table shows, among other condensed data, values of maximum resistance for the maximum compressions recorded by the various negatives:

Number of negative.		Maximum compressions.			Maximum Resistance.							
		Recorded by negative.	Measured lengths of specimen.	Elastic recovery	Graphical differentiation.	Formula $R = \frac{\sqrt{2MV}}{T}$	Static tarage.	$\Delta_{,}$	Δ'	Δ' Mean.	T Measured.	T Mean.
1		2	3	4	5	6	7	8	9	10	11	12
		inch.	inch.	inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	second.	second.
Group No. 1	1	.15347	.1486	.00487	3,808	3,994	3,570	+ 186	+ 424	+423	.0030446	.0030844
	3	.15424	.1502	.00404	3,965	3,937	3,586	— 28	+ 351		.0030885	
	4	.14955	.1491	.00045	3,933	3,984	3,500	+ 51	+ 484		.0030519	
	6	.14543	.1447	.00073	4,015	3,862	3,428	— 153	+ 434		.0031483	
Group No. 2	7	.16995	.1658	.00415	4,420	4,308	3,875	— 112	+ 433	+590	.0030317	.0029403
	8	.17079	. . .	. .	4,460	4,479	3,890	+ 19	+ 589		.0029162	
	10	.16770	.1670	.00070	4,380	4,452	3,836	— 72	+ 616		.0029337	
	11	.17268	.1709	.00178	4,542	4,417	3,930	+ 125	+ 587		.0029570	
	13	.16769	.1652	.00249	4,675	4,562	3,838	+ 113	+ 724		.0028628	
Group No. 3	21	.18866	.1870	.00166	4,725	4,732	4,240	— 7	+ 492	+401	.0042972	.0043921
	22	.22037	.2168	.00357	5,020	5,301	4,926	— 281	+ 375		.0043494	
	23	.21441	.2112	.00321	5,025	5,153	4,790	— 128	+ 363		.0044739	
	24	.21544	.2140	.00144	5,010	5,184	4,810	— 174	+ 374		.0044480	

Maximum resistances given correspond to maximum compressions recorded by negatives.

The data in column 3 came from micrometer measurements of lengths of specimens before and after compression. The variations in elastic recoveries were unexpected and are unexplained. In static machine this quantity is found to be quite uniform and equal to 0.002 inch. The values in column 5 were obtained by producing the mean resistance curves for the different negatives (Plates III, IV and V) to ordinates corresponding to the respective maximum compressions recorded. The column headed $\Delta_{,}$ shows difference between values of R given in columns 5 and 6. The values in column 6 are preferred because they agree better with data in column 2 and because the measured values of T should be more accurate than the measured values of the much smaller interval dt. Values in column 5 are also affected by errors in measured values of dc which should be larger than those in measured values of dt. Column 9 shows differences between values in columns 6 and 7.

The data in columns 10 and 12 are very important, since they indicate that the error of static tarage increases as time of compression decreases, and in an increasing ratio. We have not sufficient data for even an approximate statement of the laws of increase of this ratio. It should, of course, become infinite when $T = 0$.

Especial attention is now invited to the formula for maximum resistance herein deduced, which in general form is

$$R = \frac{AMV}{T} \quad . \quad . \quad . \quad . \quad (22),$$

in which R = maximum resistance developed in a rigidly supported specimen, MV = quantity of motion in striking mass at instant of impact, T = time consumed by resistance of specimen in generating in the mass M the negative velocity V, A = a coefficient whose limiting values are $\frac{\pi^2}{4}$ and unity.

The method for continuing this investigation and for enlarging the field of usefulness of the formula $R = \frac{AMV}{T}$, is now plain.

When we require only the *maximum resistance* developed in a specimen subjected to a blow, it is not necessary to determine the successive values of $d^2 c$ and $d t^2$. This removes at once the extremely difficult conditions which prevented the extension of this investigation to blows of less than 0.003 second duration, and renders comparatively easy the construction of an Impact Testing Machine for general use. Civil as well as military engineers will be quick to appreciate the importance of this statement. Both have recognized for a long time the necessity for such a machine. A piece of metal, a car axle for example, which is subjected almost constantly to impulsive forces while in service, should not have its dimensions calculated on the basis of static testing machine data. Railroad engineers have adopted for such pieces a system of "drop tests" to supplement static data. The "drop tests" measure the work done and, possibly, the mean resistance developed in specimen, and nothing more. It is very desirable that we should be able to determine completely the physical qualities of the specimen—its elastic limit, tensile strength, &c.—and under the condition that the forces applied shall be of the kind to which the metal is to be subjected in service.

To do this it will be necessary only to determine for the material of a specimen—just as one value has been determined by this investigation for copper—a sufficient number of values of the coefficient A, to permit the construction of its curve as a function of T. The limiting values of A are so close, $\frac{\pi}{4}$ and 1, that its curve will be accurately given by a small number of points.

Having this curve we shall have to simply strike the blow and measure its duration T. It will be observed that in the expression for R one factor, $\frac{MV}{T}$, is the *mean resistance.*

It seems more than probable that further research will enable us to determine A as a function of MV, the product of mass and impact velocity of striking weight, in which case we could use the alternate expression for mean resistance obtained by dividing the energy at impact by the *path.*

It would be easier, doubtless, to measure the path than to measure the duration of blow, and such measurement might not require the use of photography. If we could avoid the inconvenience and delay due to the use of this agent after obtaining by its aid all necessary information concerning values of A for the various materials to be tested, a much simpler form of impact testing machine would result.

By using an impact testing machine to construct our tarage tables and determining for any given conditions of loading, the *time* required for development of maximum pressure, we can use the crusher gauge and have confidence in its indications.

CONCLUSIONS.

The following conclusions, based upon this investigation, are submitted for consideration :

1. On account of elasticities of compressing weight, piston and interposed rubber disk, the first part of experimental curve does not give true values of compression for the time values recorded. A modification of the apparatus will, it is thought, remove this defect ; but it is of little importance since our principal object is to measure maximum resistances.

2. For final stages of compression, these values are far more reliable : and their indications of maximum resistances, coming

as they do from a source independent of other data at hand, may be considered as throwing additional light on a question held by some authorities to be undecided.

3. This investigation indicates that powder pressures, determined by crusher gauges with static tarage are too low, and that the probable errors from this source, where the time consumed by powder pressures in reaching a maximum is not less than 0.003 second, are between 4,000 and 5,000 pounds per square inch.

4. In all guns where the powder pressures reach a maximum in less than 0.003 second, the probable errors of crusher gauge indications based upon static tarage, will be greater than 5000 pounds per square inch. The quicker the powder the greater the error, and for this reason, the errors for small arms are greater than those for cannon.

5. When the time consumed by pressures in reaching a maximum is much less than 0.003 second, crusher gauges, with static tarage tables are of very little value, except for obtaining purely comparative data.

6. That the photo-retardograph converted into a photo-accelerograph and used to measure accelerations of gun during free recoil, a crusher gauge being simultaneously used, would give for the error of crusher gauge under service conditions the most reliable measure obtainable with any apparatus as yet developed. A moment's consideration will show this to be the case. The recoil record made as herein suggested would be similar to the experimental retardation curves presented. The acceleration curve would be convex to axis of time and tangent to it at the origin as shown in Fig. 6. The ordinates would be *magnified* movements in recoil and the abscissas would be *directly* proportional to *time* since the surface receiving record would have a practically uniform velocity. Supposing maximum pressure to correspond to point *b*, in curve *O b*, the distance *O a*, passed over by the recording surface during development of maximum pressure would be about one inch (or more if desired), whereas in the alternative method mentioned below it is, for the ten centimeter cannon, less than 0.02 in.; and *ab*, the magnified recoil, would also be one inch or more, to be again contrasted with a distance less than 0.02 inch, the actual recoil of ten centimeter cannon. When made with the

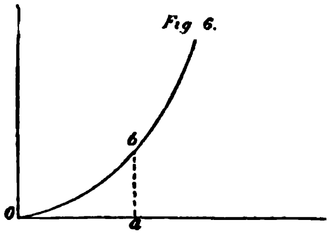
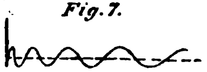


Fig. 6.

Fig. 7.



Sebert velocimeter the record is as shown in Fig. 7. The movement of gun in recoil is *not* magnified and the distances are *not* directly proportional to times. Since the ten centimeter cannon moves less than 0.02 inch while the powder pressure is reaching a maximum, and in a time somewhat less than 0.001 second, it is readily seen how unsatisfactory must be the task of differentiating this movement, especially when the unit of time is as large as 0.00187 second. At most, not more than 3 or 4 simultaneous values of time and distance can be obtained and these will be approximations only, since the integral of time to be differentiated, 0.000983 second, is less than the unit 0.001872 second.* (See Construction note, No. 62.) Now, supposing these 3 or 4 simultaneous values obtained, what is the best way to treat them? Evidently, since they are known to be approximate only, they should be graphically adjusted, or *we should have to attempt, with only approximate data for 3 or 4 points, to construct the curve (Fig. 1) which by the method proposed would be automatically and accurately produced on a magnified scale.* The difficulty experienced in producing retardation curves due to the fact that the revolving mirror and connecting masses are required to take up the impact velocity instantly, would not obtain since the whole system starts from a state of rest.

7. That the apparatus, in some form, is capable of giving a reliable dynamic measure of any quickly applied force which results in the appreciable displacement of a known mass in an appreciable time.

8. That the following is an outline of a promising plan for obtaining a time space curve for motion of projectile in the bore. Attach to base of projectile a light steel wire small enough to pass through the axial vent without deformation or sacrifice of breech block. This wire would be drawn through a rubber cork fitting the interior opening of vent. Other and very small stationary wires would pass through vent and cork to permit ignition of charge by electric primer. A very light strip of photographic film would be attached to wire in rear of gun and would move forward with it during that portion of the passage of projectile through the bore which corresponds to development of maximum pressure. An accurate time scale—such as is shown in Fig. 1, page 6, except that a fork of still higher frequency should be used—would be recorded on the film. The celluloid

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* See discussion of mechanical and photographic tuning-fork records, pages 35 and 36 of this report.

Negative No. 24. $H = 9$ inches; $W = 75.452$ pounds.

Time. 1	Designation of ordinates. 2	Copper compressions. 3 Inch.	Rate of compressions per Δt. 4 Inch	Retardation per Δt. 5 Inch.	Mean retardation per Δt. 6 Millionths inch.	Copper resistance, dynamic measure. 7 Lbs.
Time interval between compressions 1 b, 1 c, etc., = $\frac{500}{514} \Delta t$ = 0.00022822 + second.	10 a	.00124	.01887			
	11 a	.00175	.01914			
	12 a	.00246	.01926			
	13 a	.00313	.01921			
	14 a	.00414	.01891			
	15 a	.00482	.01915			
	16 a	.00584	.01904			
	17 a	.00708	.01863			
	18 a	.00825	.01835			
	19 a	.00891	.01854			
	20 a	.00990	.01826			
	1 b	.01080	.01820			
	2 b	.01184	.01788			
	3 b	.01322	.01743			
	4 b	.01374	.01792			
	5 b	.01489	.01758			
	6 b	.01611	.01736			
	7 b	.01714	.01715			
	8 b	.01813	.01715			
	9 b	.01912	.01710			
	10 b	.02011	.01690	.00197		
	11 b	.02089	.01714	.00100		
	12 b	.02172	.01697	.00229		
	13 b	.02234	.01727	.00194		
	14 b	.02305	.01731	.00160		
	15 b	.02397	.01756	.00159		
	16 b	.02488	.01720	.00184		
	17 b	.02571	.01732	.00131		
	18 b	.02660	.01714	.00121		
	19 b	.02745	.01729	.00125		
	20 b	.02816	.01744	.00082		
	1 c	.02900	.01750	.00070		
	2 c	.02972	.01754	.00034		
	3 c	.03065	.01747	—.00004		
	4 c	.03166	.01732	.00060		
	5 c	.03247	.01724	.00034		
	6 c	.03347	.01697	.00039		
	7 c	.03429	.01719	—.00004		
	8 c	.03528	.01686	.00029		
	9 c	.03622	.01699	.00011		
	10 c	.03701	.01704	—.00014		
	11 c	.03803	.01713	.00001		
	12 c	.03869	.01703	—.00006		
	13 e	.03961	.01700	.00027		
	14 c	.04036	.01711	.00020		
	15 c	.04153	.01706	.00050		
	16 c	.04208	.01737	—.00017		
	17 c	.04303	.01736	—.00004		
	18 c	.04374	.01748	—.00034		
	19 c	.04474	.01732	—.00003		
	20 c	.04560	.01745	—.00001		
	1 d	.04650	.01733	.00017		
	2 d	.04726	.01750	.00004		
	3 d	.04812	.01762	—.00015		
	4 d	.04898	.01752	—.00020		
	5 d	.04971	.01760	—.00045		
Time interval between compressions 1 b, 1 c, etc., = $\frac{500}{514} \Delta t$ = 0.00022822 + second.	6 d	.05044	.01781	—.00084		
	7 d	.05148	.01797	—.00078		
	8 d	.05214	.01777	—.00091		
	9 d	.05321	.01742	—.00043		
	10 d	.05405	.01743	—.00039		
	11 d	.05516	.01705	.00008		
	12 d	.05572	.01751	—.00048		
	13 d	.05661	.01754	—.00054		
	14 d	.05747	.01748	—.00037		
	15 d	.05859	.01708	—.00002		
	16 d	.05945	.01703	.00034		
	17 d	.06039	.01677	.00059		
	18 d	.06122	.01684	.00064		
	19 d	.06206	.01664	.00068		
	20 d	.06305	.01641	.00104		
		.06322	- - - -	- - - - -	534	2,007
	1 e	.06383	.01656	.00077		
	2 e	.06476	.01645	.00105		
	3 e	.06574	.01650	.00112		
	4 e	.06650	.01629	.00123		
	5 e	.06740	.01629	.00140		
	6 e	.06825	.01634	.00147		
	7 e	.06945	.01575	.00222		
	8 e	.06991	.01603	.00174		
	9 e	.07063	.01607	.00135		
	10 e	.07148	.01616	.00127		
	11 e	.07221	.01628	.00077		
	12 e	.07323	.01592	.00159		
	13 e	.07415	.01590	.00164		
	14 e	.07495	.01592	.00156		
	15 e	.07567	.01593	.00115		
	16 e	.07648	.01602	.00101		
	17 e	.07716	.01610	.00067		
	18 e	.07806	.01596	.00088		
	19 e	.07870	.01637	.00027		
	20 e	.07946	.01613	.00028		
		.07995	- - - -	- - - - -	778	2,923
	1 f	.08039	.01606	.00050		
	2 f	.08121	.01594	.00051		
	3 f	.08224	.01560	.00090		
	4 f	.08279	.01602	.00027		
	5 f	.08369	.01579	.00050		
	6 f	.08459	.01579	.00055		
	7 f	.08520	.01600	—.00025		
	8 f	.08594	.01589	.00014		
	9 f	.08670	.01589	.00018		
	10 f	.08764	.01587	.00029		
	11 f	.08849	.01560	.00068		
	12 f	.08915	.01589	.00003		
	13 f	.09005	.01558	.00032		
	14 f	.09087	.01554	.00038		
	15 f	.09160	.01587	.00006		
	16 f	.09250	.01555	.00047		
	17 f	.09326	.01580	.00030		
	18 f	.09402	.01550	.00046		
	19 f	.09507	.01551	.00086		
	20 f	.09559	.01554	.00059		
		.09593	- - - -	- - - - -	441	1,657

Negative No. 24.—continued. $H = 9$ inches; $W = 75.453$ pounds.

Time.	Designation of ordinates.	Copper compressions.	Rate of compressions per Δt.	Retardation per Δt.	Mean retardation per Δt.	Copper resistance, dynamic measure.
1	2	3	4	5	6	7
		inch.	inch.	inch.	Millionths inch.	Lbs.
Time interval between compressions 1b, 1c, etc., $= \frac{500}{514} \Delta t = 0.00022822 +$ second.	1 g	.09645	.01539	.00067		
	2 g	.09715	.01548	.00046		
	3 g	.09784	.01563	—.00003		
	4 g	.09881	.01535	.00067		
	5 g	.09948	.01544	.00035		
	6 g	.10038	.01538	.00041		
	7 g	.10120	.01534	.00066		
	8 g	.10183	.01534	.00055		
	9 g	.10259	.01529	.00060		
	10 g	.10351	.01519	.00068		
	11 g	.10409	.01552	.00008		
	12 g	.10504	.01514	.00075		
	13 g	.10563	.01536	.00022		
	14 g	.10641	.01527	.00027		
	15 g	.10747	.01495	.00092		
	16 g	.10805	.01521	.00034		
	17 g	.10886	.01511	.00069		
	18 g	.10952	.01515	.00035		
	19 g	.11058	.01484	.00067		
	20 g	.11113	.01499	.00055		
		.11147	- - -	- - -	701	2,634
	1 h	.11184	.01495	.00044		
	2 h	.11263	.01494	.00054		
	3 h	.11347	.01468	.00095		
	4 h	.11416	.01484	.00051		
	5 h	.11492	.01457	.00087		
	6 h	.11576	.01454	.00084		
	7 h	.11664	.01471	.00063		
	8 h	.11717	.01467	.00067		
	9 h	.11788	.01453	.00076		
	10 h	.11870	.01429	.00090		
	11 h	.11961	.01420	.00132		
	12 h	.12018	.01441	.00073		
	13 h	.12099	.01411	.00125		
	14 h	.12168	.01416	.00111		
	15 h	.12242	.01410	.00085		
	16 h	.12326	.01402	.00119		
	17 h	.12397	.01396	.00115		
	18 h	.12467	.01385	.00130		
	19 h	.12542	.01388	.00096		
	20 h	.12612	.01378	.00121		
		.12627	- - -	- - -	851	3,198
	1 i	.12679	.01391	.00104		
	2 i	.12757	.01381	.00113		
	3 i	.12815	.01403	.00065		
	4 i	.12900	.01380	.00104		
	5 i	.12949	.01388	.00069		
	6 i	.13030	.01376	.00078		
	7 i	.13125	.01339	.00132		
	8 i	.13184	.01342	.00125		
	9 i	.13241	.01359	.00094		
	10 i	.13299	.01367	.00062		
	11 i	.13381	.01367	.00053		
	12 i	.13459	.01339	.00102		
	13 i	.13510	.01354	.00057		
	14 i	.13584	.01345	.00071		
	15 i	.13652	.01353	.00057		
	16 i	.13728	.01335	.00067		
	17 i	.13793	.01332	.00064		
	18 i	.13852	.01335	.00050		
	19 i	.13930	.01327	.00061		
	20 i	.13990	.01321	.00057		
		.14023	- - -	- - -	953	3,581

Time.	Designation of ordinates.	Copper compressions.	Rate of compressions per Δt.	Retardation per Δt.	Mean retardation per Δt.	Copper resistance, dynamic measure.
1	2	3	4	5	6	7
		inch.	inch.	inch.	Millionths inch.	Lbs.
Time interval between compressions 1b, 1c, etc., $= \frac{500}{514} \Delta t = 0.00022822 +$ second.	1 j	.14070	.01209	.00092		
	2 j	.14138	.01297	.00084		
	3 j	.14218	.01276	.00127		
	4 j	.14280	.01281	.00099		
	5 j	.14337	.01285	.00103		
	6 j	.14406	.01285	.00091		
	7 j	.14464	.01283	.00056		
	8 j	.14526	.01282	.00060		
	9 j	.14600	.01264	.00095		
	10 j	.14666	.01253	.00114		
	11 j	.14748	.01232	.00135		
	12 j	.14798	.01234	.00105		
	13 j	.14864	.01232	.00122		
	14 j	.14929	.01221	.00124		
	15 j	.15005	.01216	.00137		
	16 j	.15063	.01201	.00134		
	17 j	.15125	.01204	.00128		
	18 j	.15187	.01197	.00138		
	19 j	.15257	.01180	.00147		
	20 j	.15311	.01186	.00135		
		.15328	- - -	- - -	1,217	4,573
	1 k	.15369	.01182	.00117		
	2 k	.15435	.01166	.00131		
	3 k	.15494	.01163	.00113		
	4 k	.15561	.01152	.00129		
	5 k	.15622	.01137	.00148		
	6 k	.15691	.01124	.00161		
	7 k	.15747	.01125	.00158		
	8 k	.15808	.01117	.00165		
	9 k	.15864	.01120	.00144		
	10 k	.15919	.01111	.00142		
	11 k	.15980	.01119	.00113		
	12 k	.16032	.01110	.00124		
	13 k	.16096	.01097	.00135		
	14 k	.16150	.01086	.00135		
	15 k	.16221	.01057	.00159		
	16 k	.16264	.01059	.00142		
	17 k	.16329	.01064	.00140		
	18 k	.16384	.01065	.00132		
	19 k	.16437	.01060	.00120		
	20 k	.16497	.01052	.00134		
		.16556	- - -	- - -	1,188	4,464
	1 l	.16551	.01051	.00131		
	2 l	.16601	.01049	.00117		
	3 l	.16657	.01046	.00117		
	4 l	.16713	.01032	.00120		
	5 l	.16759	.01039	.00098		
	6 l	.16815	.01027	.00097		
	7 l	.16872	.01028	.00097		
	8 l	.16925	.01018	.00099		
	9 l	.16984	.01009	.00111		
	10 l	.17039	.01008	.00103		
	11 l	.17099	.00976	.00143		
	12 l	.17142	.00993	.00117		
	13 l	.17193	.00989	.00108		
	14 l	.17236	.00996	.00090		
	15 l	.17278	.00989	.00068		
	16 l	.17323	.00992	.00067		
	17 l	.17393	.00970	.00094		
	18 l	.17449	.00955	.00110		
	19 l	.17497	.00946	.00114		
	20 l	.17549	.00943	.00109		
		.17560	- - -	- - -	1,138	4,276

Negative No. 24.—Continued. $H = 9$ inches; $W = 75.453$ pounds.

Time.	Designation of ordinates.	Copper compressions.	Rate of compressions per Δt.	Retardation per Δt.	Mean retardation per Δt.	Copper resistance, dynamic measure.
1	2	3	4	5	6	7
		Inch.	Inch.	Inch.	Millionths inch.	Lbs.
Time interval between compressions 1b, 1c, etc., $= \frac{500}{514} \Delta t = 0.00022822 +$ second.	1 m	.17602	.00937	.00114		
	2 m	.17650	.00932	.00117		
	3 m	.17703	.00932	.00114		
	4 m	.17745	.00931	.00101		
	5 m	.17798	.00913	.00126		
	6 m	.17842	.00902	.00125		
	7 m	.17900	.00886	.00142		
	8 m	.17943	.00883	.00135		
	9 m	.17993	.00881	.00128		
	10 m	.18038	.00888	.00120		
	11 m	.18075	.00891	.00085		
	12 m	.18135	.00877	.00116		
	13 m	.18182	.00846	.00143		
	14 m	.18232	.00858	.00138		
	15 m	.18267	.00857	.00132		
	16 m	.18315	.00850	.00142		
	17 m	.18363	.00841	.00129		
	18 m	.18404	.00837	.00118		
	19 m	.18443	.00845	.00101		
	20 m	.18492	.00826	.00117		
		.18451	- - - -	- - - -	1,245	4,678
	1 n	.18539	.00813	.00124		
	2 n	.18582	.00806	.00126		
	3 n	.18635	.00787	.00145		
	4 n	.18676	.00787	.00144		
	5 n	.18711	.00790	.00123		
	6 n	.18744	.00804	.00098		
	7 n	.18786	.00787	.00099		
	8 n	.18826	.00783	.00100		
	9 n	.18874	.00770	.00111		
	10 n	.18926	.00753	.00135		
	11 n	.18966	.00745	.00146		
	12 n	.19012	.00732	.00145		
	13 n	.19028	.00740	.00106		
	14 n	.19090	.00725	.00133		
	15 n	.19124	.00736	.00121		
	16 n	.19165	.00722	.00128		
	17 n	.19204	.00707	.00134		
	18 n	.19241	.00709	.00128		
	19 n	.19288	.00689	.00156		
	20 n	.19318	.00689	.00137		
		.19320	- - - -	- - - -	1,270	4,772
	1 o	.19352	.00690	.00123		
	2 o	.19388	.00686	.00120		
	3 o	.19422	.00678	.00109		
	4 o	.19463	.00668	.00119		
	5 o	.19501	.00660	.00130		
	6 o	.19548	.00643	.00161		
	7 o	.19573	.00646	.00141		
	8 o	.19609	.00640	.00143		
	9 o	.19644	.00638	.00132		
	10 o	.19679	.00627	.00126		
	11 o	.19711	.00632	.00113		
	12 o	.19744	.00621	.00111		
	13 o	.19768	.00622	.00118		
	14 o	.19815	.00605	.00120		
	15 o	.19860	.00589	.00147		
	16 o	.19887	.00585	.00137		
	17 o	.19911	.00586	.00121		
	18 o	.19950	.00574	00135		
	19 o	.19977	.00574	.00115		
	20 o	.20007	.00569	.00120		
		.20060	- - - -	- - - -	1,313	4.934

Time.	Designation of ordinates.	Copper compressions.	Rate of compressions per Δt.	Retardation per Δt.	Mean retardation per Δt.	Copper resistance, dynamic measure.
1	2	3	4	5	6	7
		Inch.	Inch.	Inch.	Millionths inch.	Lbs.
Time interval between compressions 1b, 1c, etc., $= \frac{500}{514} \Delta t = 0.00022822 +$ second.	1 p	.20042	.00551	.00139		
	2 p	.20074	.00548	.00138		
	3 p	.20100	.00548	.00130		
	4 p	.20131	.00540	.00128		
	5 p	.20161	.00529	.00131		
	6 p	.20191	.00520	.00123		
	7 p	.20219	.00522	.00124		
	8 p	.20249	.00504	.00136		
	9 p	.20282	.00496	.00142		
	10 p	.20306	.00494	.00133		
	11 p	.20343	.00481	.00151		
	12 p	.20365	.00481	.00140		
	13 p	.20390	.00476	.00146		
	14 p	.20420	.00469	.00136		
	15 p	.20449	.00461	.00128		
	16 p	.20472	.00459	.00126		
	17 p	.20497	.00451	.00135		
	18 p	.20524	.00441	.00133		
	19 p	.20551	.00430	.00144		
	20 p	.20576	.00421	.00148		
		.20568	- - - -	- - - -	1,321	4,963
	1 q	.20593	.00425	.00126		
	2 q	.20622	.00416	.00132		
	3 q	.20648	.00414	.00134		
	4 q	.20671	.00403	.00137		
	5 q	.20690	.00399	.00130		
	6 q	.20711	.00391	.00129		
	7 q	.20741	.00378	.00144		
	8 q	.20753	.00378	.00126		
	9 q	.20778	.00371	.00125		
	10 q	.20800	.00368	.00126		
	11 q	.20824	.00361	.00120		
	12 q	.20846	.00349	.00132		
	13 q	.20866	.00348	.00128		
	14 q	.20889	.00340	.00129		
	15 q	.20910	.00334	.00137		
	16 q	.20931	.00322	.00127		
	17 q	.20948	.00318	.00133		
	18 q	.20965	.00311	.00130		
	19 q	.20981	.00311	.00119		
	20 q	.20997	.00308	.00113		
			- - - -			
	1 r	.21018	.00020			
	2 r	.21038	.00024			
	3 r	.21062	.00012			
	4 r	.21074	.00015			
	5 r	.21089	.00013			
	6 r	.21102	.00017			
	7 r	.21119	.00012			
	8 r	.21131	.00018			
	9 r	.21149	.00019			
	10 r	.21168	.00013			
	11 r	.21185	.01155			
	12 r	.21195	.01130			
	13 r	.21214	.01105			
	14 r	.21229	.01080			
	15 r	.21244	.01055			
	16 r	.21253	.01030			
	17 r	.21266	.01005			
	18 r	.21276	.00980			
	19 r	.21292	.00955			
	20 r	.21305	.00930			

film is sufficiently light and tough to permit a sudden arresting of its motion without mutilation of record. The wire would remain attached to projectile. The advantage of causing the projectile to *pull* rather than to *push* an attachment to secure a time record is evident. In the latter case the rigidity necessary to prevent buckling requires an excess of mass in the attachment. The light steel wire would be kept straight by tension; it could readily stand the slight tortional strain due to rotation of projectile; and the resistances to its motion, due to the slight friction in guides and to the small mass of wire and film would not cause an appreciable stretch in it.

In case of constrained recoil a preliminary measurement of recoil should be made by attaching the film to some part of gun or carriage in order to apply to the projectile record the slight correction due to recoil. For free recoil this correction would be supplied by the well known formula which connects the motions of gun and projectile while the latter is in the bore.

For rapid fire guns and small arms a non-recoil mount would dispense with the necessity for this correction.

PROFESSIONAL NOTES.

ORGANIZATION.

Argentine Republic.

The permanent army, on the first of October, 1896, had the following organization and strength: 1 regiment of engineers, 34 officers and 400 men, comprising 2 companies *sapeurs mineurs*, 1 company of pontoneers, 1 company of telegraphers and a section of railroad engineers; 6 regiments of field artillery, each composed of 20 officers and 391 cannoneers, forming 3 batteries; 1 regiment of mountain artillery, of the same strength as those of field artillery, but formed into 6 batteries; 10 regiments of cavalry, each of 3 squadrons, and each having a strength of 32 officers and 350 men; and 12 regiments of infantry, each of 4 companies, and each counting 26 officers and 400 men.

This makes a total of 103 field officers, 703 company officers and 11,437 men. For the command of these troops, which are organized in 4 divisions, there are 5 lieutenant-generals, 8 division generals and 21 brigadiers, who each have a numerous staff.

The budget of expenses of the permanent army in 1897, as fixed by the minister of war, amounts to a sum total of 8,947,356 pesos, or 44,739,780 francs.

—*Revue du Cercle Militaire*, November 21, 1896.

ARTILLERY MATERIAL.

a. Guns and Carriages.

A Study on a New Matériel for the Swiss Artillery.

The artillery commission in 1892 prepared a program for some trials of new field and mountain pieces. This program was drawn up designedly on broad and little defined lines, as the constructors had to be allowed great liberty. A small number of the latter responded by submitting plans in which practical qualities especially were lacking: they were the designs of engineers, not of artillerists. Colonel Schumacher, chief of the artillery arm, then asked for authority to detail an officer for the special study of a new matériel; Lieutenant-Colonel Pagan, first-class instructor, was chosen for this duty.

The object of these lines is not to give a *critique* of this important work, an undertaking for which we lack the necessary competence, but we would desire to give our readers as complete an analysis as possible.

I. FIELD ARTILLERY.

Program.—In consequence of the improvements made in small arms in recent years, artillery is passing at present through a period of change and transformation; the different countries hesitate to introduce, at the price of great sacrifices, a new material the defects of which might be avoided and the progress thereof developed by others who have profited by acquired experience.

It is essential, however, to study the changes to be made, under penalty of being taken wholly unprepared at the very moment when the necessity for this transformation definitely imposes itself. The unity of conception that should constitute *the* value of the new matériel, ought to be attained by means of theoretical study made wholly as much from a tactical as from a technical point of view; the artillerist should indicate precisely to the constructor the arm that he wishes given him, but he ought to ask of the latter only that one which, in the present state of technical science, is possible practically.

Power and Mobility.—"The conditions of power and of mobility cannot be laid down precisely in any absolute manner. If great power is demanded, the matériel has to be made of great weight; if, on the contrary, maximum mobility is required, diminution of power must be expected. Progress in mechanical arts has indeed permitted an increase in both power and mobility at the same time. but these two qualities are none the less in opposition."

Tho weight of the piece being once determined, we must utilize it in making it give the maximum effect, either the *maximum* effect with a *minimum of ammunition*, or the maximum effect in a *minimum of time*.

A heavy projectile produces in one spot more effect than a light projectile, but more shots can be fired with a light projectile and less *weight* of ammunition and less *time* will be expended in attaining correctness of fire; hence, within a certain limit, a superiority for the light projectile.

Moreover, it must be determined whether the efficiency in regulated fire is not proportional to the weight of the projectile; experience and theory both show that, under the same conditions of remaining velocity, angle of opening of the sheaf of bullets and precision of fire, the same weight of ammunition will produce a greater effect with a large number of light projectiles than with a small number of heavy projectiles. But at long ranges, the conditions are no longer identical and the superiority of the light projectile tends to diminish.

The gun we ought to seek for is one having more mobility than our present one, but possessing *at least higher* power and capable of maintaining a duel against heavier guns due to the efficiency of its projectile, the rapidity of its fire and its great amount ot ammunition. Our pieces with carriages weigh 1,950 kg. (4,290 pounds), without cannoneers; it ought to be possible to bring that down to 1,200 kg. (2,640 pounds). This lesser weight will permit the use of four horses for drawing them; thence will follow more regular and easier draft, diminution of the length of columns, also in the vulnerability of the battery and finally ability to make the best use of the *terrain*. The supply of ammunition could, moreover, be increased, and at the same time the number of caissons.

Mutual dependence of the elements of a field matériel.—This chapter successively examines the various elements of a system of artillery: muzzle energy and its production, remaining energy, weight of projectile, caliber, sectional and spherical density, behavior of the projectile in firing, pressure in the gun, powder, energy of recoil of the piece and resistance of the carriage, energy of recoil of the piece in battery.

From this examination, the authors of the work deduce various elements for the construction of pieces and carriages in the details of which it is difficult to enter; but it is to be noted that they admit that rapidity of fire depends more upon improvement in pointing and aiming together with the suppression of recoil than upon improvements in breech mechanisms and ammunition; but that up to the present time, the problem of the complete suppression of recoil has not yet been solved.

Calculations and determinations.—This chapter examines questions relative to the density of the projectile, initial velocity and muzzle energy, relations between the weight of the piece and that of the carriage and to the supply of ammunition of the battery, which should be about 200 rounds per piece.

DETAILS OF CONSTRUCTION.

The second part of the work, entitled *Details of Construction*, reviews successively the piece, the ammunition and the carriage, and points out the solutions to numerous questions that will confront the constructor.

The piece.—The piece, of 75 mm. caliber, should be of a metal having at least the qualities of nickel steel. It will be wire-wound, having a preponderance of about 25 kg. (55 pounds), and a length of 2.2 m. (7.2 feet) or 29 calibers. There will be 24 grooves with a twist increasing from 2° to 6°; the breech mechanism to be chosen preferably from those of the screw systems: either interrupted screw or eccentric screw fermeture.

Ammunition.—Shrapnel will continue to be the normal projectile. In addition to shrapnel, each battery should have a small supply of torpedo shells (*obus-torpilles*) which might even be transported only in the ammunition wagons of the army corps.

The bullets of the shrapnel should be as numerous as possible, therefore they cannot be made very heavy; on the other hand if they are too light, they lose their velocity too soon. The construction of the shrapnel should be such that the ratio of the weight of the charge to the weight of the projectile will be the greatest possible, in other words the effect of the balls of the shrapnel is to be a maximum.

To bring about this result, the body and diaphragm of the projectile must be made of metal offering the greatest resistance to deformation and the smallest admissible thickness must be adopted. The bursting charge should be as small as possible, yet large enough to furnish a puff convenient for the observation of the shot and to increase sufficiently the velocity of the balls.

The fuze for the shrapnel will be a combination fuze of long duration with graduations for time of flight, permanently assembled, containing a good fuze composition protected from moisture. The so-called mechanical fuze, being too delicate, should be discarded.

The important question of the adoption of fixed ammunition is examined with the greatest care and is finally decided in the negative. The advantage which the fixed ammunition appears to offer, especially in rapidity of fire, is more apparent than real; the true cause of slowness of fire is principally due to delay in pointing.

"It is in quick pointing that rapidity of fire must be sought; consequently one must seek to suppress the recoil, or diminish it, or else so divide the work of the cannoneers that pointing, aiming and loading may be carried on at the same time."

The carriage.—The deformation carriage not presenting the desired qualities, we must adopt the rigid carriage of sheet steel, maximum weight, and furnished with an automatic brake. The recoil will be greater than that of our present pieces, but the increase thereof will be compensated by increased facility of running the piece by hand into the firing position.

Is it necessary to provide our pieces with a shield to protect the cannoneers from infantry fire and shrapnel bullets? In spite of the complication of matériel, increase in weight of piece and inconvenience in the service, they are now in favor. This question also has not been definitely solved; the experiments must be continued and it must be shown whether or not the shield is a serious embarrassment to maneuvering the piece.

The following table gives the firing data for the 75 mm. (2.925 in.) gun, with a projectile weighing 5.8 kg. (12.76 pounds) and 6.8 kg. (14.96 pounds), constructed according to these conditions:

(a) Weight of shrapnel . . . . 5.8 kg. (12.76 lbs.)
Number of balls of 11 grm (170 grains) 263
Initial velocity . . . . 500 m. (1,640 f. s.)

Range.	Angle of projection in sixteenths of a degree.	Angle of fall in sixteenths of a degree.	Remaining velocity.	Angle of the sheaf of balls. (degrees.)	Diameter of the sheaf at 50 m. (164 ft.) from the point of burst.	Density of the sheaf at 50 m. (164 ft.) (balls per square meter.)	Efficient depth of the sheaf for 8 kgm. (57.8 foot pounds.)
			m.	°	m.		m.
—	—	—	500	$10\frac{15}{16}$	9.54	3.708	341
1000	24	29	362	$14\frac{3}{16}$	12.7	2.08	317
2000	61	88	294	$17\frac{11}{16}$	15.2	1.45	295
3000	113	168	260	$19\frac{4}{16}$	16.9	1.174	281
4000	178	276	232	$21\frac{2}{16}$	18.6	.970	260
5000	261	417	208	23	20.3	.816	238
6000	385	650	188	$24\frac{14}{16}$	22	.690	215

(b) Weight of shrapnel . . . . 6.8 kg. (14.96 lbs.)
Number of balls of 11 grm. (170 grains) 309
Initial velocity . . . . 500 m.

—	—	—	500	$10\frac{15}{16}$	9.54	4.357	—
1000	22	27	380	$13\frac{15}{16}$	12.2	2.65	—
2000	57	79	308	$16\frac{10}{16}$	14.6	1.85	—
3000	105	151	274	$18\frac{6}{16}$	16.2	1.502	—
4000	162	245	248	$19\frac{15}{16}$	17.6	1.273	—
5000	236	370	226	$21\frac{9}{16}$	19	1.088	—
6000	331	512	206	$23\frac{8}{16}$	20.5	.938	—

The least advantageous ballistic coefficient has been selected.

Limber and caissons.—These parts should be lengthened and improved. The limbers of the caissons should be like those of the pieces, and the rear carriage similar to the limber. The middle rail, carrying the lunette should be movable so as to admit of substituting a pole when it is desired to use the rear carriage of the caisson as a limber.

This arrangement, when occasion requires, would permit the ammunition to be brought to the battery on a two-wheeled vehicle, each part being used separately, thus securing sufficient mobility to pass, by horse or by hand, across the most difficult *terrain.*

CONCLUSIONS.

The first part of the second work, which treats exhaustively of the future mountain artillery, we pass over at present in order to take up the author's conclusions.

The efforts that all artillerists are making to introduce new matériel are not the result of coincidence; they are the necessary result of progress in ammunition. The latter, for a long time of secondary consideration, although efficacy of fire depends upon it above all, now occupies the first place.

Two conclusions may be drawn from the numerous experiments made with our excellent shrapnel with base charge.

1st. That the maximum of efficiency must be sought, not in the absolute velocity of the projectile, but in conditions of construction such that the axis of the shrapnel shall make with the trajectory the smallest possible angle.

2nd. That the shrapnel of larger caliber, even though it carries more balls and may have a greater efficient range and greater useful depth of sheaf does not produce greater effect at ordinary ranges; the superiority of the large caliber against targets formed of thin lines is not in direct proportion to the number of balls, and the number of figures struck is almost the same. Small caliber and rapidity of fire give the maximum effect in the shortest time.

The inferior limit of caliber is determined by the fact that it must permit correct observation. To fulfil this condition at least 7 cm. is required. The easy service of the piece determines the superior limit of the caliber of the field gun, which ought not to be greater than 8 cm.

So we fix upon 75 mm. as the greatest caliber which, in the present state of construction of carriages, allows control of the recoil, without subjecting the piece to considerable lateral displacement at each discharge.

The diminution of caliber has, on the one hand, the advantage of increasing the number of projectiles carried, and on the other hand, of increasing the mobility, if a certain definite number of rounds is fixed as the supply.

From the tactical point of view the increase of real power due to the lighter projectiles ceases to be in opposition to mobility, the lighter projectiles assuring either the maximum effect in the minimum time or the maximum number of hits per kilogram of projectile.

The greater mobility acquired, thanks to the new matériel, will facilitate the concordant action of infantry and artillery by permitting them to maintain in action better than in the past that close relation which ought to be their ideal.

Unity of *construction*, with but one kind of gun and a single kind of projectile; unity of *tactics*, with the artillery in condition to readily accompany and support the infantry; and finally, unity of *organization*, with the field and mountain artillery mutually supplementing each other, that is the end which this study aims to attain.

The study drawn up by the bureau of artillery is a work already so condensed, comprising in one small volume such a considerable amount of matter, set forth with such clearness and precision, that the task of him who is called upon to abridge it becomes singularly delicate and difficult.

We have endeavored to give a faithful though brief analysis of this work, but fear that we have only partially succeeded.

—*Revue Militaire Suisse*, October 15.

[Translated by Lieutenant C. C. WILLIAMS, 4th Artillery.]

The new 10-inch Wire-Wound, Segmental Gun for the United States Army.

The Ordnance Department has taken in hand the construction for experimental purposes of an altogether new type of gun, which is likely to show an efficiency far in advance of the hooped gun which is the standard type for the United States army and navy to-day. The new weapon of 10-inch caliber and 30 tons weight, will be known as a Brown segmental, wire-wound gun, and will be the second of its type to be built; the first, a 5-inch gun, having been built four years ago by the inventor, Mr. J. H. Brown, and tested by the government at the United States proving grounds, Sandy Hook, in December, 1893, and again in May, 1896. The tests consisted of 200 rounds, fired with both brown and smokeless powder, when the gun was subjected to excessive powder pressures, the maximum reaching 65,600 pounds to the square inch, and developed the high muzzle velocity of 3,235 feet per second, without showing any signs of failure.

Although the principles upon which the wire-wound gun is constructed are thoroughly scientific, they are simple and easily understood. If the modern gun were made in one piece, as were the old cast-iron guns, the enormous pressure of the powder gases would stretch the metal lying nearest the bore of the gun beyond its elastic limit before the overlying metal nearer the circumference could come into play and assist in taking the strain.

To correct this fault guns are built up in a series of overlying cylindrical rings, each ring being shrunk on over the others, with the result that the innermost tube is thrown into a state of initial compression. It is evident that upon firing such a gun the shock of discharge will be instantly felt and resisted by every one of the cylinders or "hoops," as they are called, and every particle of metal, from the bore to the circumference of the gun, will be doing useful work. The strength of a built-up gun will depend upon the amount of initial compression and tension which the inner tube and the outer layers can respectively be made to carry, and this in turn depends, of course, on the elastic strength of the metal employed. Many years ago it occurred to a Mr. Longridge, in England that if instead of shrinking on hoops, a high grade of steel wire were wound onto the inner core of the gun at a high tension, a much higher compression of the inner tube could be obtained and greater powder pressures and velocities would be possible. He built an experimental gun which verified his theories, but failed because sufficient provision had not been made for longitudinal strength. The system was ultimately taken up by Mr. Armstrong in England, who overcame the difficulties of longitudinal weakness and produced a wire-wound gun, which has been adopted as the standard weapon for the whole British navy.

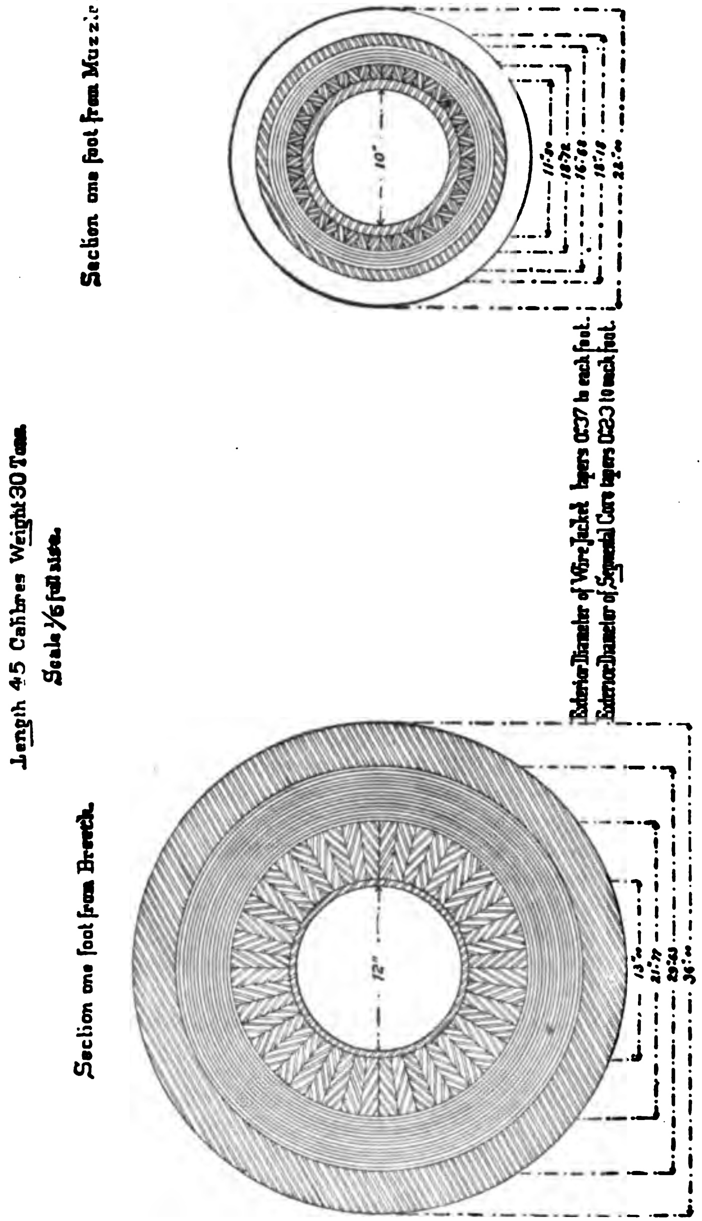
Now, the limit of strength of the ordinary wire-wound gun will be the elastic strength of the inner core of the gun (for it is evident that the metal must not be compressed beyond its elastic limit), and the elastic limit will be dependent upon the possibilities of manufacture.

Mr. Brown conceived the idea of building up the internal tube with a number of longitudinal steel bars or staves and wrapping them together under the tension of the steel wire. By this means he was able to secure a core having a much higher elastic limit than was obtainable in an ordinary tube.

The advantages of this system of making the core are thus stated by Lieutenant G. N. Whistler in his admirable theoretical discussion of the Brown segmental system:

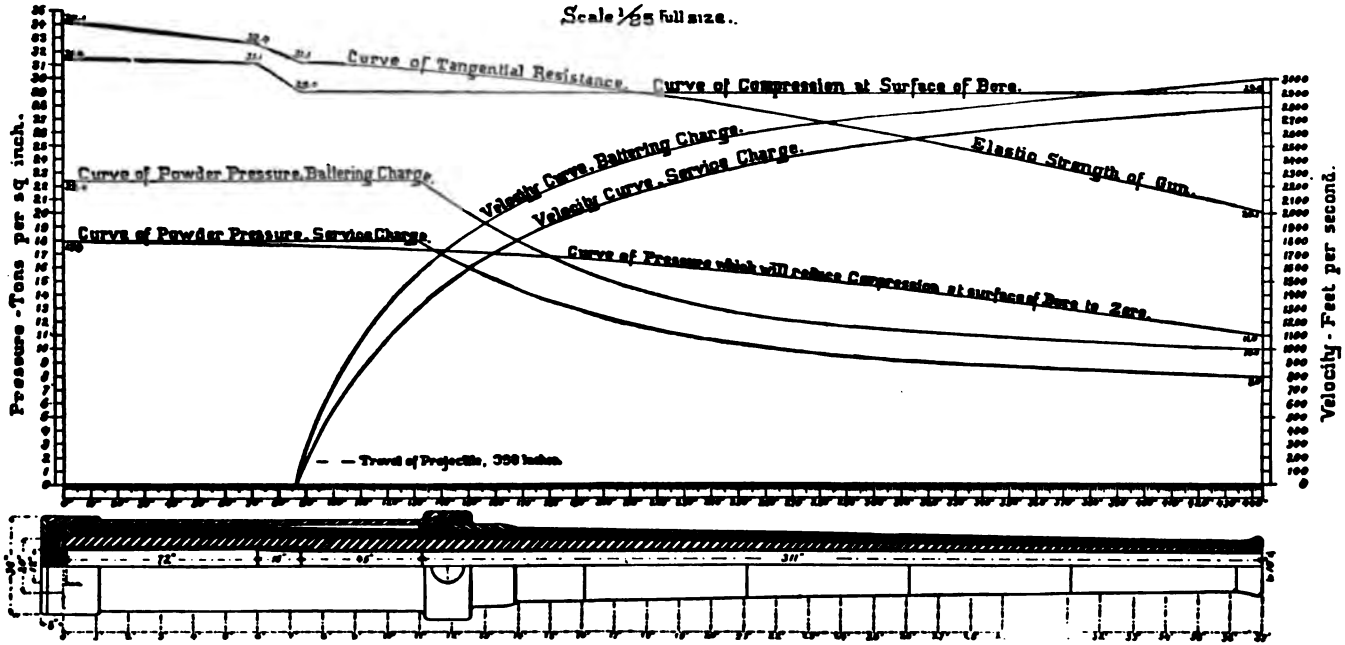
1.—In consequence of the small weight of each of the component parts of the gun, crucible steel can be used economically. 2.—The small size of the segments, and the ingot from which they are rolled, admits of their being carefully cast and uniformly forged, so as to insure uniformity of metal and its being thoroughly annealed. 3.—As they can be readily rolled into shape, the method of construction is exceedingly economical. 4.—They can be thoroughly and conveniently inspected. 5.—The size and thinness of each segment insures a thorough and uniform tempering and annealing, if temper be considered desirable. 6.—The size of the segments admits of readily setting up conditions of special elasticity by cold work.

The latter feature is by far the most important one in this system of construction, as it renders it possible to use a character of steel far beyond anything heretofore employed in the core of a gun. The core of such a gun

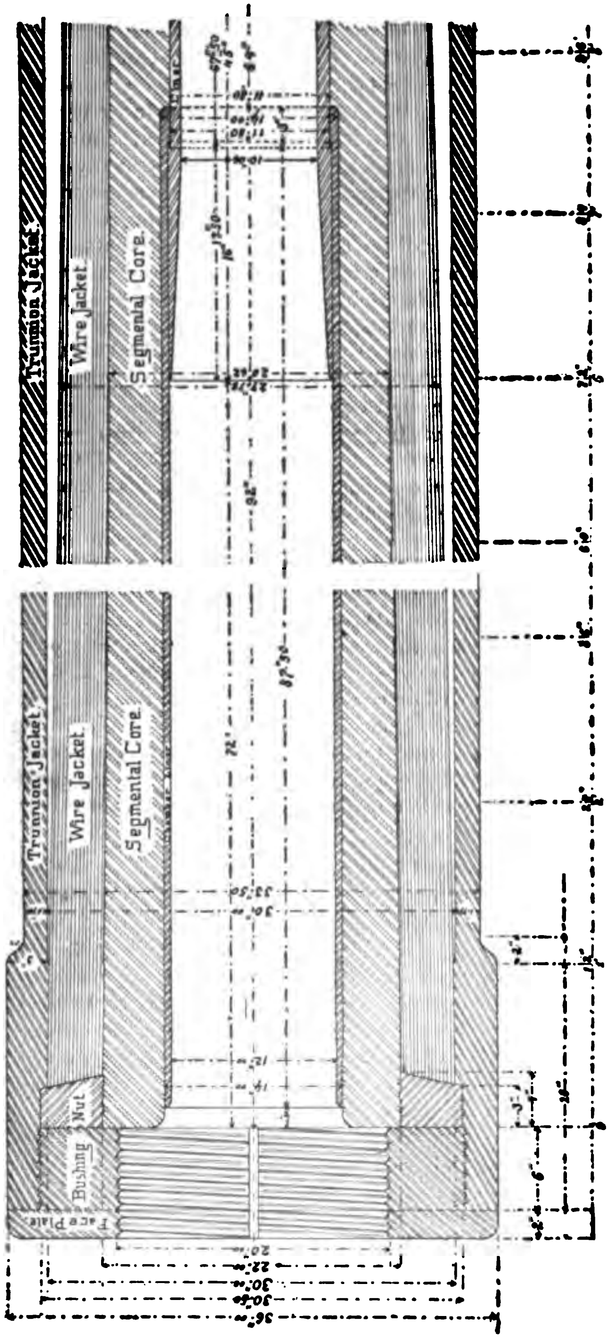

Section one foot from Muzzle.
10"
11.50
13.72
16.60
18.18
22.00
Length 45 Calibres Weight 30 Tons.
Scale 1/6 full size.
Exterior Diameter of Wire Jacket tapers 0.37 in each foot.
Exterior Diameter of Segmental Core tapers 0.23 in each foot.
Section one foot from Breech.
12"
13.00
21.77
29.20
36.00

Length 4·5 Calibres. Weight 30 Tons.

Scale 1/25 full size.



whose bars or shoes have been hardened, annealed and cold drawn could readily be wound so as to produce a compression between the segments of



Length 45 Calibres Weight 30 Tons.

Scale 1/8 full size.

Details of Inserting Liners.

Details of Breech.

112,000 pounds to the square inch without exceeding the elastic limit of the weapon.

In the manufacture of the 10-inch Brown gun the production of the segmental core is the most novel feature. The segments, which are made from open hearth steel, are cold drawn and are tapered and beveled in the working. This is done so accurately that no machining is necessary. They are assembled vertically, with the large end down, in much the same way as a cooper assembles a barrel, and are temporarily held together with three-part clamps placed one foot apart. The core is then put in a lathe, the two ends are machined, and the breech and muzzle nuts are shrunk on. The lathe is then set at the taper of the finished gun, and the outside of the core is turned down from nothing at the breech nut to a depth equal to the thickness of the wire, at twelve inches from said nut. Here the operation is again repeated for another twelve inches, and so on until the muzzle nut is reached. The steel wire is $\frac{1}{7}$ of an inch square in section, with a sectional area of $\frac{1}{49}$ of an inch. The end of the wire is keyed into the gun at the breech nut and it is wound on at the required tension by means of the automatic winding machine shown in the accompanying cut. When the wire reaches the shoulder it is tightly wedged in against it, turned over, and keyed into the gun. The next layer is started at the second shoulder, 24 inches from the breech nut, and wound back to the breech. The third starts at the breech and runs to the third shoulder, the successive layers running in contrary directions until the necessary amount of wire is laid on. The gun is then bored out, heated internally by gas, and shrunk onto a thin steel liner. The chase jacket is shrunk on in two-foot sections. The trunnion jacket is interlocked at the breech end by shrinking on, and fits with a slip joint over the chase. The breech closure is screwed into the projecting end of the jacket, and the trunnion ring is screwed on over the front end of the same jacket, as shown, so that the recoil of the gun is taken up directly by the jacket and transferred by the trunnions to the gun carriage. The longitudinal stress is taken in part by the longitudinal segments. In addition to this, the method of cross-wrapping the wire in itself imparts considerable longitudinal strength to the gun.

The winding of the wire at a constant tension is done by the ingenious machine shown in the engraving. It consists of a stout frame, bolted to the lathe carriage, which is provided with a large overhead spool to carry the wire, and a small car which runs on a track at right angles to the axis of the gun. Upon the car are journaled two sets of adjustable steel rollers, between which the wire passes and by means of which the necessary tension is given to the wire as it passes to the gun. The pressure between the rollers is regulated by means of coil springs, controlled by thumbscrews. The two sets of rollers are geared to two brake wheels, which are seen above and below the car. The upper brake wheel has a fixed brake. The lower brake is automatic in its action and is controlled by the position of the car. From the rear of the car a set of wires passes over the pulley which is seen suspended between the vertical frames, and down to a bracket which carries a certain amount of dead weight. The winding is started with the weight resting on the floor. The handwheel on the brake is then turned until the weight is raised, when the tension in the wire equals the weight. As the car travels toward the gun, the brake wheel is released by an automatic gear and the car soon finds a position of equilibrium. The brakes are kept cool by the water pipes shown in the engraving.

The wire used in the construction of the 10-inch gun will have a total length of 75 miles.

The high quality of steel which it is possible to use in the segmental wire gun is evident from the official tests of the metal put into the 5-inch gun of this pattern. The segments showed an elastic limit of 126,000 pounds per square inch and an ultimate strength of 176,000 pounds per square inch; the wire shows an elastic limit of 230,000 pounds and an ultimate strength of 262,000 pounds per square inch.

We would direct our readers' attention, bearing these figures in mind, to the accompanying diagram showing the curves of velocity, pressure, and resistance, from which it will be seen that, when using the battering charge, which gives the enormous velocity of 3,000 feet per second, the curve of powder pressure is never beyond 60% of the elastic strength of the gun. If the segmental wire gun has the necessary endurance, and the army trials at Sandy Hook demonstrate that it has, its superiority over the hooped system of construction is obvious, and explains why the English navy has adopted the Armstrong wire gun as its standard weapon. For with the higher velocities of which the wire-wound gun is capable, the energy of the projectile per ton weight of the gun is enormously increased, with the result that of two ships of equal size, carrying the same total weight of guns, the ship armed with the segmental wire gun will have an enormous superiority of fire. For the same weight it can carry more weapons of equal power, or the same number of weapons of greater power.

This can best be shown by a comparison of the naval 10-inch gun Mark II, of 28 tons weight, and the Brown 10-inch gun of 30 tons weight which is now being built. The hooped navy gun has a muzzle energy of 15,285 foot tons, whereas the Brown gun, which is only two tons heavier, will have 37,800 foot tons energy, which, be it said, is over 4,000 foot tons greater than the energy of the 13-inch hooped gun now in service.

Limits of space prevent any further discussion of this very live question. Enough has been said to show that the government is fully justified in its determination to build a gun of large caliber and give it a thorough test. It is not enough to say that our hooped guns are the best of their kind; we must have the best of any kind, and if the performance of the segmental wire gun is as good in the large as it has been in the small calibers, we cannot too soon adopt it as the service weapon for both army and navy.

—*Scientific American*, November 28, 1896.

b. Armor and Projectiles.

Krupp 8-cm (3.1-in) Face-Hardened Nickel-Steel Plate No. 476 A.

(*Concluded from page* 107.)

Dimensions of the plate: Thickness 8 cm. (3.1 in.), length 1.21 m (4 feet), width 1.70 m. (5.6 feet).

Rounds I-V were fired against the plate and a backing, which consisted of 30 cm. (11.8 in.) oak, which both were secured to a forged iron bulkhead with 40 mm. (1.6 in.) 2 × 20 mm. (2.0 × 8 in.) inner skin by means of 4.55 mm. (2.2 in.) nickel-steel bolts. Angle of impact, 87°. Rounds VI-IX were fired against the plate without backing. Angle of impact, 48°.

	No. of impact.	GUN.		Ratio of caliber to thickness of plate.	PROJECTILE.		Distance of plate from muzzle of gun.	VELOCITY.			
		Caliber.	Length.		Kind.	Weight.		a Muzzle velocity.	b Striking velocity.	c Velocity required to perforate an ordinary steel plate of equal thickness.	d Ratio b:c.
						kg. lbs.	m. f.	m. f.	m. f.s.	m. f.	
Angle of impact: 87°.	I	8.8 cm. (3.5 in.) Q.F.	L/24	1.1	*Krupp* A. P. steel shell L/2.6 Powder charge 0.7 kg. (1.5 lbs.) W.P. C/89	7.0 15.4	99 324.8	469.6 1540.7	453.7 1488.5	449.4 1474.4	1.01
	II	"	"	"	" Powder charge 1.05 kg. (2.3 lbs.) W.P. C/89	"	"	627.6 2059.1	606.8 1990.8	"	1.35
	III	10.5 cm. (4.1 in.) Siege.	L/35	1.25	" L/3.1 Powder charge 3.4 kg, (7.5 lbs.) P.P. C/68	16.0 35.3	"	439.7 1442.6	430.4 1412.1	339.4 1113.5	1.27
	IV	"	"	"	" Powder charge 3.6 kg. (8.6 lbs.) P.P. C/68	"	"	474.1 1555.5	464.1 1522.7	"	1.37
	V	15 cm. (5.9 in.)	L/30	1.88	" L/2.8 Powder charge 3.3 kg. (7.3 lbs.) W.P. C/89	40.0 88.2	121 397.0	415 1361.6	406.5 1333.7	279.2 916.0	1.45

ROUNDS VI-IX. ANGLE OF IMPACT 48°. NO BACKING.

Angle of impact: 48°.	VI	10.5 cm. (4.1 in.) Siege.	L/35	1.25	*Krupp* A.P. steel shell L/3.1 Powder charge 2.1 kg. (4.6 lbs.) W.P. C/89	16.0 35.3	100 328.1	527.8 1731.7	516.3 1693.3		
	VII	"	"	"	" Powder charge 2.6 kg. (5.7 lbs.) W.P. C/89	"	"	629.6 2065.7	616.4 2022.3		
	VIII	"	"	"	" Powder charge 2.35 kg. (5.2 lbs.) W.P. C/89	"	"	578.3 1897.3	565.8 1856.3		
	IX	"	"	"	" Powder charge 2.225 kg. (4.9 lbs.) W.P. C/80	"	"	553.1 1814.7	541.1 1775.3		

Striking energy.	Thickness of plate which the shell would have perforated according to French formula		Penetration of point of projectile.	EFFECTS ON PROJECTILE.	EFFECTS ON PLATE.	No. of impact.
	Ord'ry steel.	Iron.				
mt. fts.	cm. in.	cm. in.	cm. in.			
73.44 237.0	9.8 3.9	10.5 4.1	0.5 0.2	Broken up.	Indentation 5 mm. (0.2 in.) deep and 80 mm. (3.1 in.) in diameter. Back of plate: no effect.	I
131.4 424.0	12.2 4.8	16.4 6.5	?	Broken up, point of projectile welded into the plate.	Indentation 120 mm. (4.7 in.) in diameter. Depth could not be measured. Below the impact two concentric cracks. The plate was bulged to the rear to a height of 13 mm. (0.5 in.) and 150 mm (5.9 in.) in diameter	II
151.1 487.6	11.2 4.4	14.9 5.9	?	Broken up.	Indentation 120 mm. (4.7 in.) in diameter. The plate was bulged to the rear to a height of 30 mm. (1.2 in.) and 225 mm. (8.9 in.) in diameter with a concentric crack.	III
175.6 534.4	12.5 4.9	16.8 6.6	3.5 1.4	Broken up, point of projectile welded into the plate.	Indentation 35 mm. (1.4 in.) deep and 140 mm. (5.5 in.) in diameter. The plate was bulged 250 mm. (9.8 in.) in diameter.	IV
336.9 1087.2	13.7 5.4	18.4 7.2	through.	Broken up into larger fragments. Fragments perforated the plate and passed into the backing.	Projectile perforated plate, backing and thin plating behind the framework. A section of the rear face of the plate about the point of impact was driven into the backing, the timbers were considerably crushed.	V

ROUNDS VI-IX. ANGLE OF IMPACT 48°. NO BACKING.

217.4 701.6			1.0 0.4	Broken up and fragments rebounded.	Indentation 10 mm. (0.4 in.) deep and 100 mm. (3.9 in.) in diameter with a concentric crack. The plate was bulged to a height of 5 mm. (0.2 in.) and 125 mm. (4.9 in.) in diameter.	VI
309.8 999.7			through	Broken up, fragments in front and in rear of the plate.	Point of impact near the edge of the plate.	VII
261.1 842.6			"	Broken up, fragments in front and in rear of the plate.	Projectile perforated plate and punched out a section which was driven into the backing.	VIII
238.8 770.6			8 3.1	Broken up and fragments rebounded.	Not perforated. Indentation 80 mm. (3.1 in.) deep. The plate was bulged to a height of 100 mm. (3.9 in.) and 300 mm. (11.8 in.) in diameter.	IX

Krupp 8 cm. (3.1 in.) Face-Hardened Nickel-Steel Plate, No. 476 B.

No. of impact.	GUN.		Ratio of caliber to thickness of plate.	PROJECTILE.		Distance of plate from muzzle of gun.	VELOCITY.			
	Caliber.	Length.		Kind.	Weight.		a Muzzle velocity.	b Striking velocity.	c Velocity required to perforate an ordinary steel plate of equal thickness.	d Ratio b : c.
					kg. lbs.	m. f.	m. f.	m. f. s.	m. f.	
I	8.8 cm. (3.5 in.) Q.F.	L/24	1.1	*Krupp* A.P. steel shell L/2.6 Powder charge 0.70 kg. (1.5 lbs.) W.P. C/89	7.0 15.4	95 311·7	468.1 1535.8	452.2 1483.6	449.4 1474.4	1.07
II	"	"	"	" Powder charge 1.0 kg. (2.2 lbs.) W.P. C/89	"	"	605.3 1985.9	585 1919.3	"	1.18
III	"	"	"	" Powder charge 1.05 kg. (2.3 lbs.) W.P. C/89	"	"	629.6 2065.7	608.7 1997.0	"	1.35
IV	10.5 (4.1 in-) Siege.	L/35	1.25	" L/3.1 Powder charge 3.4 kg. (7.5 lbs.) W.P. C/68	16.0 35.3	99 324·8	428.6 1406.2	419.6 1376.7	339.4 1113.5	1.53

Dimensions of the plate: Thickness 8-cm. (3.1 in.), length 1.14 m. (3.7 feet), width 1.5 m (4.9 feet).

The plate and the backing which consisted of 30 cm. (11.8 in) oak, were secured to a forged iron framework with 40 mm. (0.8 in.) 2 × 20 mm. (2 × 0.4 in.) inner skin. Angle of impact, 87°.

Striking energy.	Thickness of plate which the shell would have perforated according to French formula		Penetration of point of projectile.	EFFECTS ON SHELL.	EFFECTS ON PLATE.	No. of impact.
	Ord'ry steel.	Iron.				
mt. fts.	cm. in.	cm. in.	cm. in.			
72.96 235.4	9.8 3.9	10.5 4.1	0.2 0.1	Broken up and fragments rebounded.	Indentation 2 mm. (0.1 in.) deep and 40 mm. (1.6 in.) in diameter. Back of plate uninjured.	I
122.1 394.0	11.7 4.6	15.6 6.1	1.0 0.4	Broken up and fragments rebounded.	Indentation 10 mm. (0.4 in.) deep and 150 mm. (5.9 in.) in diameter. The surface of the plate was flaked off. The plate bulged to the rear, to a height of 5 mm. (0.2 in.) and 125 mm. (4.9 in.) in diameter.	II
132.2 426.6	12.3 4.8	16.5 6.5	1.8 0.7	Broken up.	Indentation 18 mm. (0.7 in.) deep and 160 mm. (6.3 in.) in diameter. The hard surface of the plate was considerably flaked off about the point of impact. There was a bulge on the rear face 200 mm. (7.9 in.) in diameter and 13 mm. (0.5 in.) high.	III
143.6 463.4	10.8 4.3	14.3 5.6	through.	The broken up point of the projectile, together with the punched out section passed into the second layer of the backing. The remainder of the projectile rebounded.	The shot perforated the plate, punching out a section which passed into the backing, crushing the timbers in a considerable way.	IV

The author remarks on this trial:

"Both 80-mm. (3.1 in.) plates stood the trial without receiving cracks; there were even no traces or indications of cracks. The 8.8 cm. (3.5 in.) gun was not capable of breaking the resistance of the plates. But, while the plate 476 B was perforated by the 10.5 cm. (4.1 in.) shell with a striking energy of 143.6 mt. (463.4 foot tons), whereby a section was punched out, the plate 476 A has resisted the attack of the 10.5 cm. (4.1 in.) shell, though both rounds were fired under the same circumstances. Also impact III was not able to perforate the plate 476A with a striking energy of 151.1 mt (487.7 foot tons). This remarkable difference of power of resistance can likely be accounted for by a different treatment of both plates. More recent trials of 80 mm. (3.1 in.) *Krupp* plates are said to have shown the result, that the 10.5 cm. (4.1 in.) shell did not perforate the plate with a striking velocity of 527 m (1729 ft)."

"It may be taken for granted that at close range the 10.5 cm. (4.1 in.) gun has sufficient power to perforate the 80 mm. (3.1 in.) armor, while at long range the 12 cm. (4.7 in.) gun is needed."

"The results of these very important ballistic trials will effect a considerably more extensive use of such thin plates. They will no doubt have a great influence on shipbuilding and will contribute to strengthen the power of attack of battleships."

Armor Plate Resists Projectiles.

A Carnegie Harveyized plate representing a 600-ton lot of the side armor of the *Kearsarge* kept out two projectiles from a ten-inch rifle at Indian Head to-day in a remarkable manner. The plate was of the tapering pattern, its thickness being 16½ inches at the top and running off to 9½ at the bottom. The first shot struck it with a velocity of 1,380 feet a second, and after getting its nose only two inches into the metal bounded out, leaving the plate uninjured. The second projectile was started with the maximum velocity of 1,850 feet a second and was intended to penetrate the plate or smash it in the effort. It embedded itself to the depth of seven inches, and the plate, remaining unharmed, passed the ordeal magnificently. The lot will be promptly accepted.

—*New York Tribune*, March 19, 1897.

Turret of the Battleship Massachusetts Under Fire.

An experimental turret, representing similar structures on the United States battleship *Massachusetts*, was tested last spring under conditions such as will obtain in an actual sea fight, and we are now enabled to present our readers with photographic reproductions which show how it stood the ordeal.

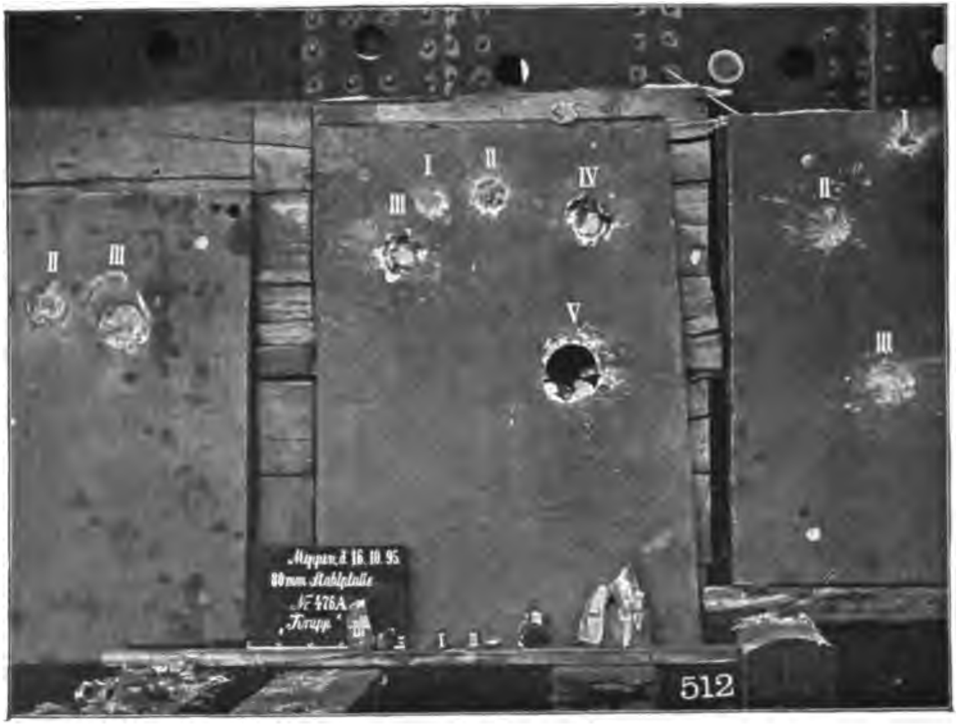
The ballistic tests which are continually being made upon armor plate furnish very complete information regarding its ability to keep out projectiles. There is not a battleship in any of the navies of the world regarding which a naval expert could not tell us the powers of resistance possessed by its armor. There are other questions, however, to be considered in addition to that of the mere resistance of armor to penetration. The plate would afford but little protection unless it were well supported or "backed" by the framing of the ship itself. Even if a shell should fail to get through, there is a possibility that it will drive the plates bodily within the structure of the ship, racking and distorting the skeleton framework to which the armor is bolted. Our readers will remember the test made late last year of a structure representing the sides of the battleship *Iowa*, which was illustrated in the *Scientific American* of November 9. The results showed that the framing had ample strength to hold the plate up against the heaviest shells.

It was felt by the Bureau of Ordnance, however, that the experiments would not be complete until a test had been made of the armored turrets of our battleships. The fact that the framework of the ship itself could stand the impact of heavy projectiles was no proof that the revolving turrets, which carry the big guns, would be equally secure. A slight deformation of the plates and beams of the backing, which would be of but little consequence in the fixed sides of the ship, might interfere with the working of a huge turret, rotating as it does on a circle of steel rollers, and having clearances of only a few inches between itself and the walls of the barbette. Even if the structure of the turret itself were not distorted, it was possible that it might be moved bodily upon its supports, in which event the elaborate gear, hydraulic or otherwise, for turning the turret would be disabled, and the whole mass, with its two big guns, constituting one-half the main fighting power of the ship, become wedged in its seat and rendered all but useless.

It was determined to make a test of an experimental turret which should be practically, at least for the purposes of the test, a facsimile of the turret of the battleship *Massachusetts*. A solid foundation of piling covered with heavy timber was built, and upon this was laid a circular track of wrought-iron plates, answering to the roller track of the *Massachusetts*. The experimental turret

FIGURE 6.

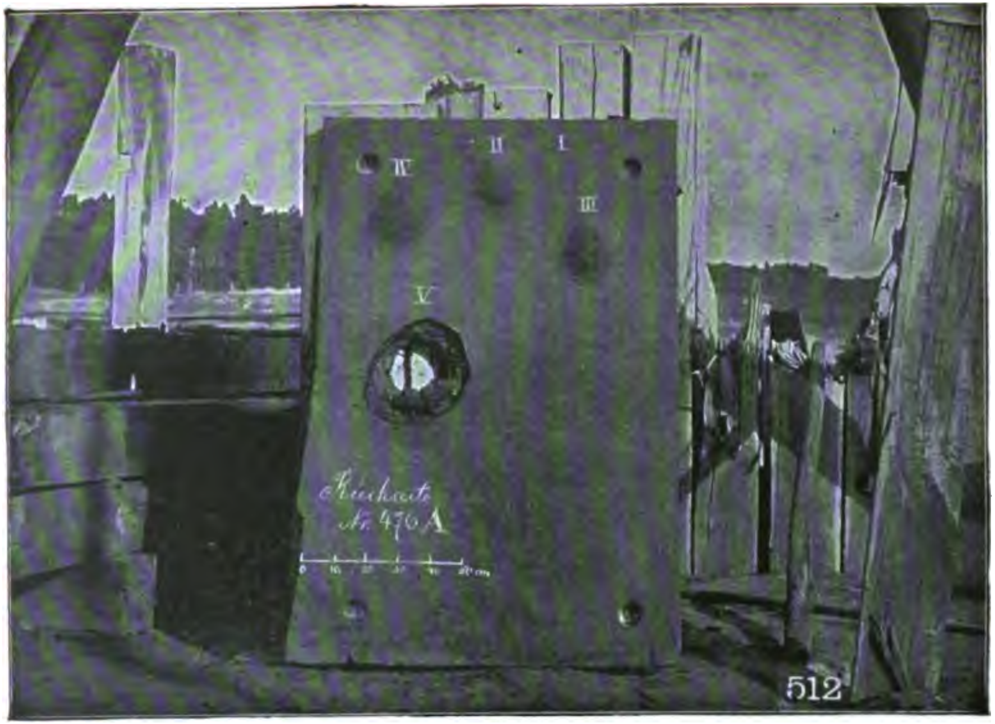
Krupp 80-mm. (3.2-in.) face-hardened nickel steel plate No. 476A.



Front of Plate after 5 rounds.

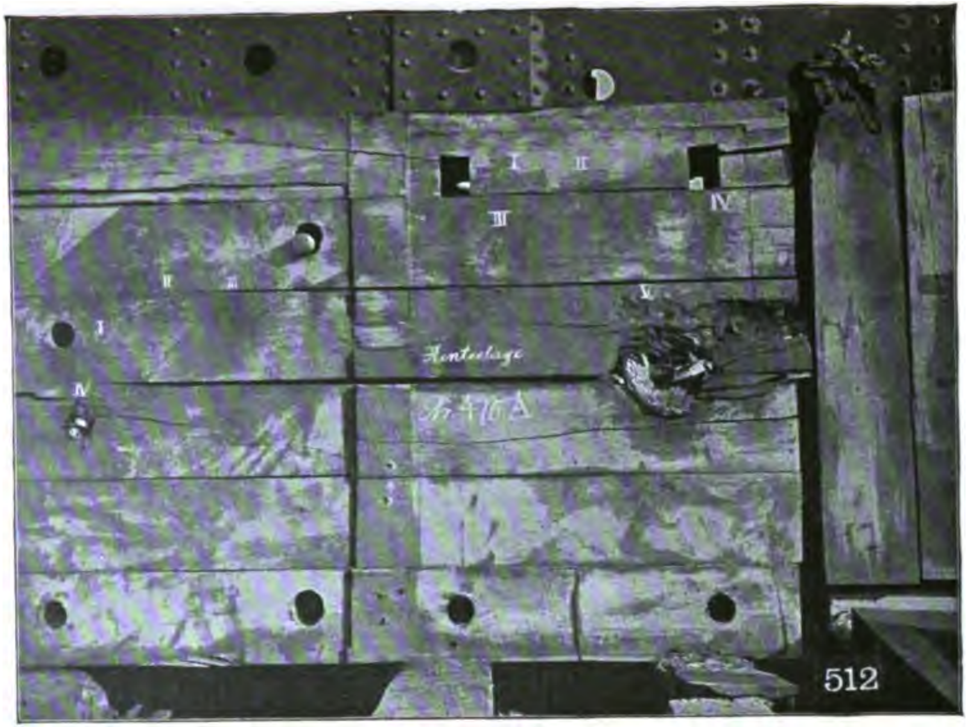
FIGURE 7.

Krupp 80-mm. (3.2-in.) face-hardened nickel steel plate No. 476A.



Back of Plate after 5 rounds.

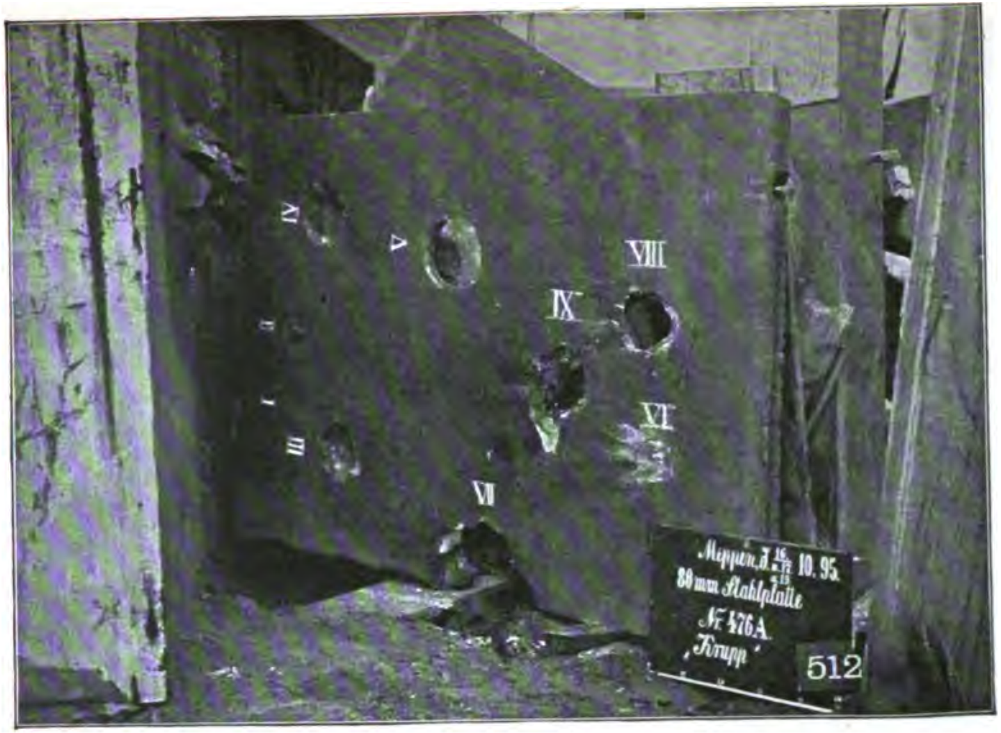
FIGURE 8.



Backing of *Krupp* 80-mm. (3.2-in.) face hardened nickel steel plate No. 476A after five rounds.

Figure 9.

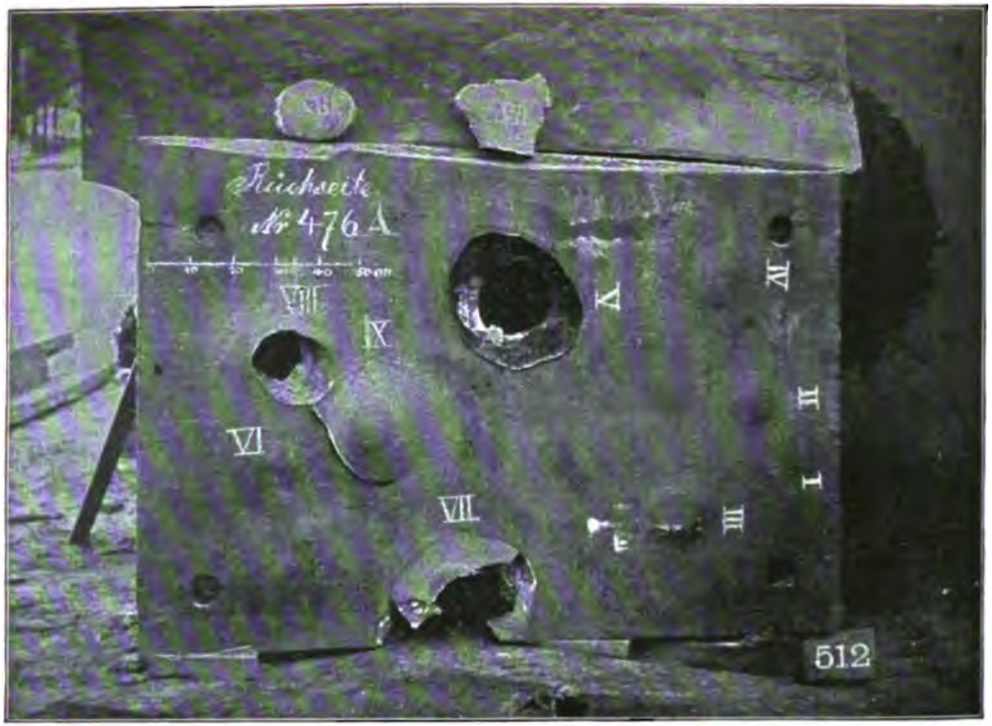
Krupp 80-mm. (3.2-in.) face-hardened nickel steel plate No. 476A.



Front of Plate after 9 rounds.

Figure 10.

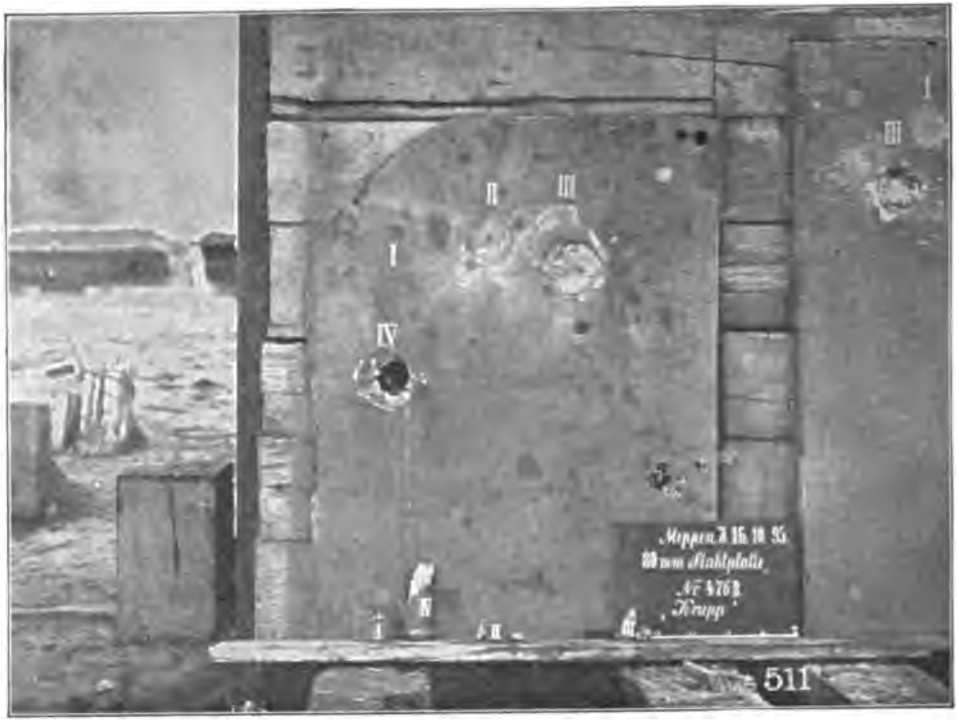
Krupp 80-mm. (3.2-in.) face-hardened nickel steel plate No. 476A.



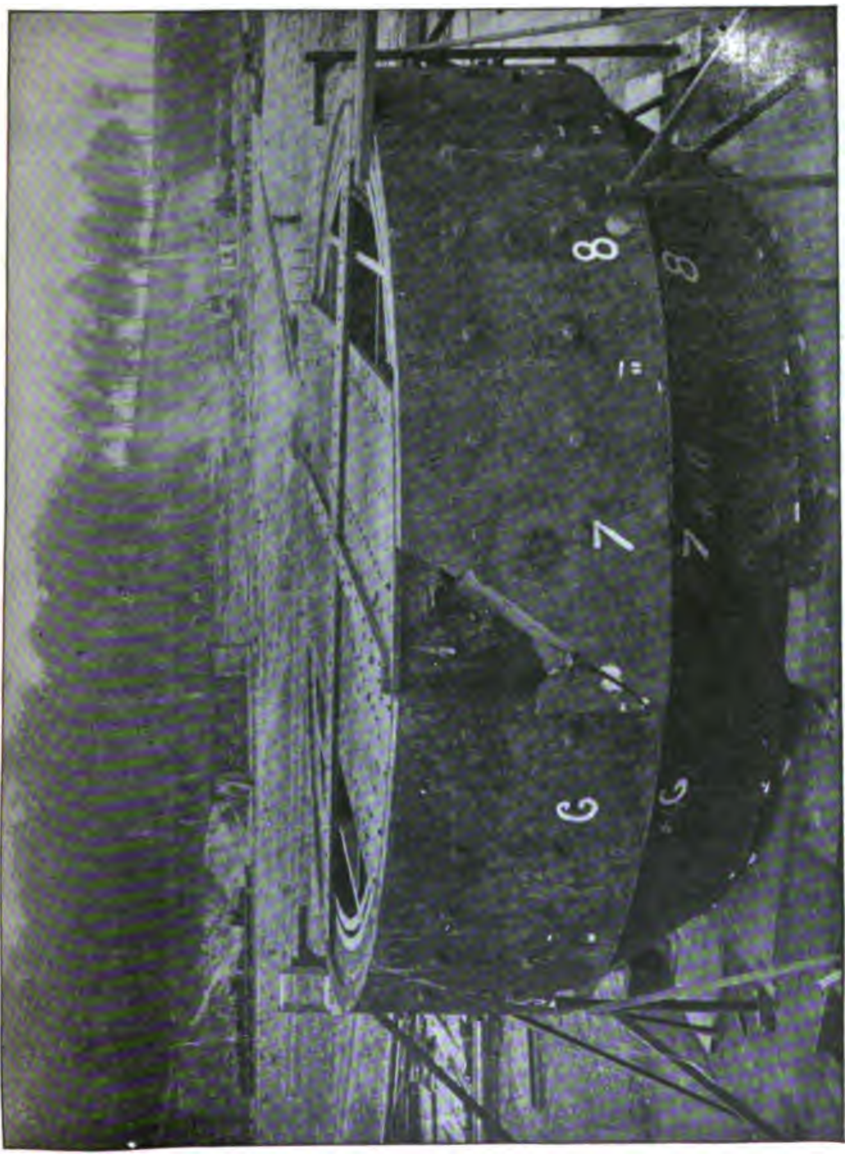
Front of Plate after 9 rounds.

FIGURE 11.

Krupp 80-mm. (3.2-in.) face-hardened nickel steel plate No. 476B.



Front of Plate.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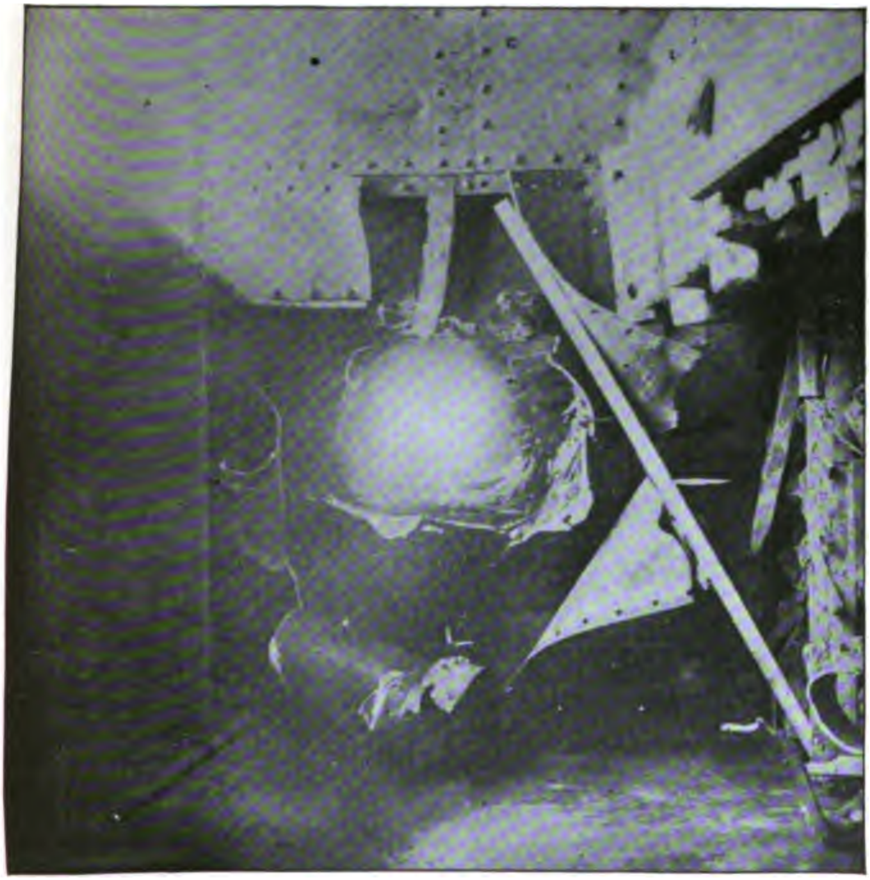
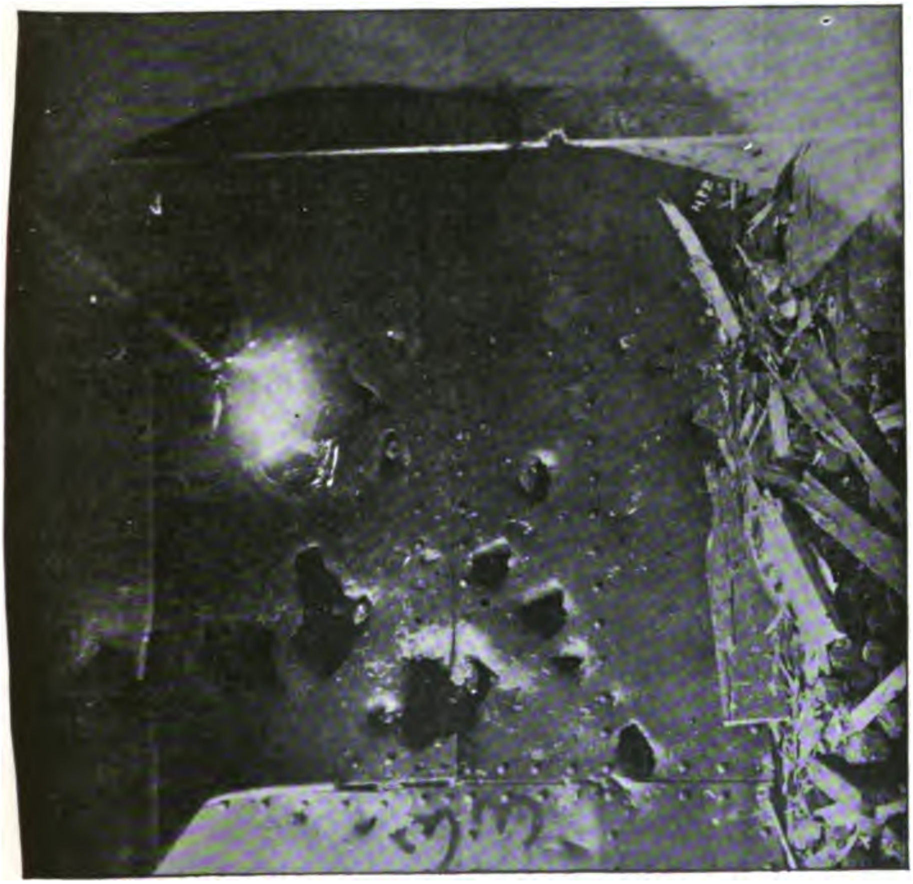




was 27 feet interior diameter and 11 feet high. Its framework, consisting of vertical angle frames and horizontal channel irons, carried ten cast-iron plates, 15 inches thick, and one steel test plate representing the turret armor of the *Massachusetts'* interior girders, similar to those used for carrying the gun, were built in place, and 180 tons of pig iron were so disposed within the turret as to represent the actual weights of the gun and gear. The weight of the complete structure was 450 tons, and it was carried on twenty cylindrical rollers of steel, which were prevented from transverse movement by means of wrought-iron wedges. The experimental steel plate was one which had already been used in experimental tests, and had successfully resisted two heavy armor piercing shells, the points of which were embedded within it. In the present experiment three rounds were fired, as per the accompanying table:

	Round 1.	Round 2.	Round 3.
Gun	10-inch.	12-inch.	12-inch.
Projectile	500 pounds.	850 pounds.	851 pounds.
Velocity	1,683 foot secs.	1,701 foot secs.	2,000 foot secs.
Energy	9,829 foot-tons.	17,069 foot-tons.	23,626 foot-tons.

The first shell, a 10-inch Wheeler-Sterling, broke upon the plate with a penetration of 9½ inches. The point of impact was 14½ inches from the top of the plate and 2 feet to the left of the second of the points of impact above mentioned. A piece of the plate above the point of impact, 33 inches wide, was carried away, and the roof plates of the turret were wrenched upward to a height of 1 inch. The armor bolts were uninjured and there was no movement of the plates on the turret. The whole turret was moved backward on its rollers for a distance of 1¾ inches.

The second shell struck the turret at an angle of 7½° from the normal. This projectile penetrated 11½ inches and broke up, the head remaining welded to the plate. The plate was cracked diagonally through the last shot hole and through one of the old points of impact to the bottom of the plate. One armor bolt was broken and driven into the turret. The adjoining cast iron plate to the right was slightly displaced. The horizontal channel irons of the framework were buckled to the extent of one inch. The splinter bulkhead to the left was buckled to the extent of 3 inches. The turret itself was carried to the rear a distance of 7¼ inches, and was also turned about its axis slightly. There was no distortion of the structure considered as a whole.

The third shot was a Johnson fluid compressed steel armor piercing shot, similar to that shown in our last week's issue, but 12 inches in diameter. It carried a soft steel cap and weighed 851 pounds. It struck the plate at an angle of 21° from the normal, at a point about 3 feet from the left edge and 3 feet from the top of the plate. It will be noticed that the angle of impact was very large, and when the shot struck the plate, instead of following the line of fire, it turned sharply to the right and passed entirely through the plate on a line nearly normal to its surface.

The shot broke up in forcing its way through, the larger pieces going through the covering plate on the rear side of the turret, piercing the backing, smashing off a large portion of the rear cast-iron plate, and finally going into the woods behind the target.

The destructive effect of the shot is shown very graphically in the accompanying illustrations. The back of the ballistic armor plate was broken out for a diameter of two feet around the hole; pieces of the steel being driven through the turret and scattering in all directions. The backing was carried away and splintered; the plating behind the backing being folded back and wrecked over an area of 3½ feet square. Rivets were sheared and flew all over the turret, leaving their marks on the interior. The channel beam at the rear of the shot hole was ripped off and thrown across the turret. A jagged hole, 7 inches in diameter, was torn through an adjoining deck beam. The interior vertical covering plates on the opposite side of the turret were pierced with eighteen holes and showed numerous deep gouges and scars caused by the flying fragments. The turret structure over an area of 4 square feet where the shot struck was badly wrecked. The backing on the rear side was wrecked and splintered and the 15-inch cast-iron plate badly cracked, two large pieces of the latter being thrown to the rear, leaving a triangular hole 4 feet high and 4 feet wide. All six of the armor bolts holding these plates were broken, and the plate itself was forced to the rear 9 inches on one edge and 2 inches on the other. This impact moved the turret 9 inches to the rear in a direction making an angle of nearly 8° with the line of the movement in the two previous impacts. It also revolved around its center to the left through an angle of 2°. The result of the test proves that the framing of the turret has ample strength to resist the heaviest strains that could come upon it under fire. The fact that the turret as a whole moved as much as 9 inches under the energy of the shot raises the question of the sufficiency of the means adopted to hold the turrets of our battleships in place. As at present constructed, the tendency to translation of the turret is resisted by the flanges of the steel rollers upon which it revolves, and it is estimated by Commodore W. T. Sampson that these flanges present an ample margin of strength to resist the shearing action to which they are subjected. When the 33,000 foot-tons of energy of a 13-inch shot is communicated to the turret, a part of it is expended in piercing or breaking up the plate and part of it causes the whole turret to move until the roller flanges take hold of the edges of the roller track. According to the last authority, the pressure of a 13-inch gun against its recoil cylinders when it is fired brings a strain upon the roller bearings far greater than they can ever experience under the momentum of a heavy shot. Altogether this very interesting test establishes the excellence of the system of turret coustruction as carried out in our new battleships.

Referring again to the photographs showing the destruction wrought in the interior of the turret by the flying fragments of the successful shot, it is evident that had the turret been occupied by actual guns, and gun crew, the gun itself and the larger part of the crew would have been disabled. It is also noteworthy that successful penetration was effected in spite of the fact that the shot struck at a high angle of incidence, and there is no doubt but what it was largely due to the action of the soft steel cap, as explained in our last issue.

—*Scientific American*, December 12, 1896.

The Victory of Shot Over Armor.

We present in this issue an excellent half-tone engraving of what may justly be called the most successful penetration of Harveyized armor plate on record, which was made by a Johnson solid shot at the naval proving ground, September 5. The penetration of 10 inches of nickel steel, face hardened, reforged plate by a 6-inch shot, as shown at the point marked No. 3 in the engraving, is in itself a phenomenal performance, and places the gun once more far in the lead. But when our readers learn that, after penetrating the plate, the shot passed through 12 inches of oak and three plates $\frac{7}{16}$ inch thick, and was finally found 8 feet back in the sand and practically uninjured, they will understand how complete is the superiority of the best type of shot over the best type of armor to-day.

It is a matter of history that, just at the time when armor plate makers were discouraged by the ease with which the gun makers were able to penetrate the toughest nickel steel, Mr. Harvey produced his brilliant invention for giving an intensely hard face to the plate, and succeeded in smashing up the projectiles at the moment of impact. Shots which theoretically should have passed clear through a Harveyized plate failed to do so, because their points could not hold together long enough to break in through the highly tempered face, which was made so hard that it could cut glass like a diamond point.

Subsequent to the appearance of Harveyized armor the makers of projectiles have been trying to produce a shot which should combine the necessary hardness and toughness to enable it to split open the hardened face and hold together until it had wedged its way through the body of the plate itself. A few of the best makers have met with partial success. The Holtzer in Europe and the Sterling-Wheeler in this country have succeeded in breaking up the face; but the effort has proved too much for the shell, which has usually collapsed before it could get entirely through the plate. This has been the case almost invariably when the improved reforged Harvey plate has been attacked. The result is shown very clearly in the case of shot No. 1 in the recent trials, when an 8-inch Holtzer shot, weighing 250 pounds, and fired with a velocity of 1,800 feet a second, entered the plate and broke up, leaving the point embedded.

For many months the reforged Harveyized plate held its superiority, and it looked as though the final victory in the long contest between shot and armor was to rest with the armor. The next move on the part of the artillerist was of a very extraordinary, but very successful kind. He placed a cap of soft steel over the point of the shot to protect it, and, paradoxical as it may appear, the soft cap enabled the shot to get through.

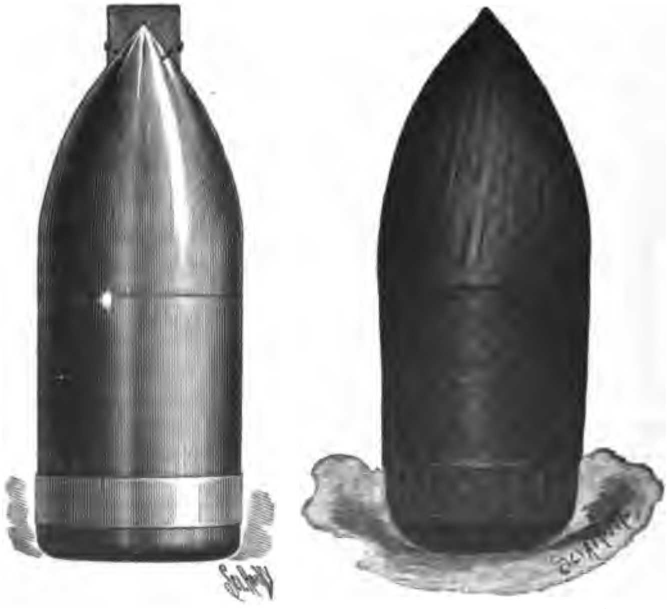
The part played by the cap may best be explained by a simple experiment which can easily be tried by any of our readers. An ordinary sewing needle may be driven through a copper cent piece by thrusting it through a cork until the point is flush with the bottom of the cork, placing it upon the copper cent, preferably over an anvil, and giving the head of the needle a sharp tap with a light hammer. The copper will be cleanly perforated. The surrounding cork holds the body of the needle in the line of the blow, so that its whole force is concentrated at the point. The action of the cap is somewhat analogous. It preserves the integrity of the point of the shot at the moment of impact, holding the material together until penetration through the hard face is effected. Moreover, the cap becomes fused by the heat of concussion and lubricates the point as it enters. After the face is broken through, the Johnson shot holds together by virtue of its peculiarly hard and tough composition, which is obtained by a secret process of manufacture.

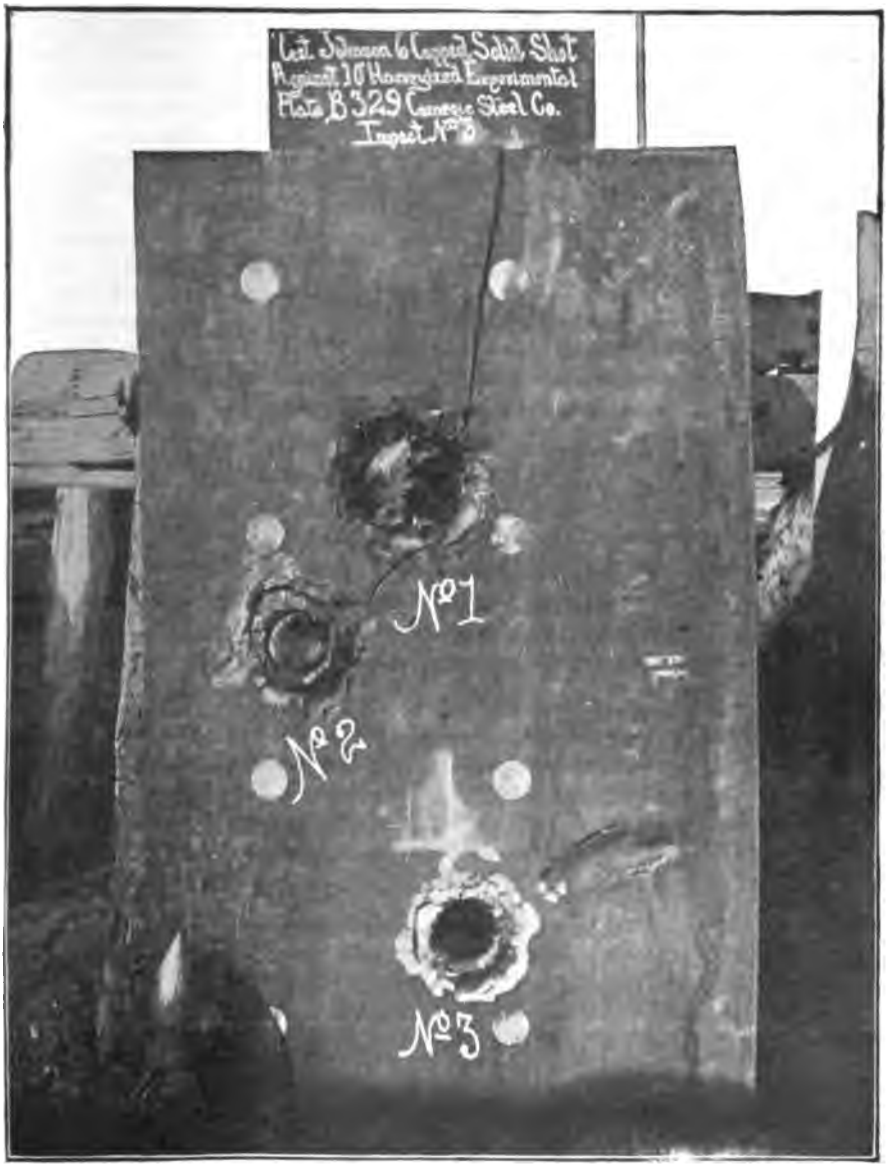
Referring again to the photograph of the plate, shot No. 2 represents a 6-inch 100-pound Johnson shot which was fired with brown powder at a velocity of 2,100 feet per second. It penetrated to a depth of 8 inches and communicated all of its theoretical capacity at that velocity, the rear portion of the shot breaking off and rebounding from the target. Mr. Johnson was confident that if the shot were given greater velocity, it would make a clean penetration, and accordingly a charge of 28 pounds of torpedo station smokeless powder was inserted for the next round. The shot, weighing 105.25 pounds, stuck the target with a velocity of 2,505 foot seconds and an energy of 4,594.8 foot tons at a point 21.5 inches normally from the bottom, and 32 inches from the left edge of the plate. The work of the shot, which passed through the plate practically uninjured, can best be given in the words of the official report:

Action of projectile.—Projectile penetrated plate, backing, boiler plates, and was recovered 8 feet back in the sand, entire, with the exception of one-half of base broken off diagonally to the bandscore. The remaining portion of the shell was in excellent condition, with the point whole, the head slightly scored, increased in diameter at the bourrelet 0.15 inch and in body 0.06 inch; length decreased 0.49 inch. Two small surface longitudinal cracks in the body 5.5 inches and two inches long, also two in the head 1.5-inch and 2.5 inches long, respectively. Four fragments recovered; total weight, 95 pounds; weight of the shell proper, 85 pounds.

Effect on plate.—Penetration complete; diameter of shot-hole, 6⅛ inches; interior for about 3.5 inches rough, with fused metal, rest of hole smooth, all the interior being coated with copper, probably from the rifling band. Diameter of splash and flaking, 13 inches, ⅝-inch deep. The boiler plate backing was star opened to a diameter of 16 inches.

A comparison of the two cuts, showing the projectile before and after firing, will show the wonderful endurance of the shot. The deep scorings on the conical head were produced by the jagged edges of the hardened armor face, and the twist imparted by the rifling is plainly discernible. The corrugated recess at the base is the seating for the copper rifling band, which, as the report states, was sheared off in the shot-hole, together with diagonal fragments of the base. Altogether this is by far the most brilliant performance of any shot in any country, and the two photographs which are now presented to the public for the first time are well calculated to carry dismay into




Lt. Johnson 6 Capped Solid Shot
Against 10 Harveyized Experimental
Plate B 329 Carnegie Steel Co.
Impact No 3
No 1
No 2
No 3

the camp of the armor plate makers. Messrs. Johnson & Company, of Spuyten Duyvil, New York, are to be congratulated on a success which has come as the result of many years of costly experiment; and the country at large will be pleased to think that, if Harvey's plates have been signally beaten, it is an American projectile that has done it.

Incidentally it should be noted that the success of the second Johnson shot was only achieved by using a high velocity, considerably higher than the 2,000 feet per second which is obtained with the standard brown powder used for United States ordnance. Mr. Johnson is asking for 3,000 feet per second in order to develop the full potentiality of this solid shot; and it must certainly be admitted that the introduction of smokeless powder, with its higher velocities, would be an advance along the lines which are being universally followed by the gun makers of England and the Continent. The 10-inch Brown segmental wire gun now in course of construction by the government will have a maximum velocity with smokeless powder of 3,000 feet per second, and would seem to be the natural counterpart of the Johnson shot. The *St. Louis* and the *St. Paul* are designed to carry a battery of 6-inch guns, and if these guns were to be of the wire-wound pattern, and the ammunition included smokeless powder and a certain number of rounds of Johnson shot, these cruisers would have three-fourths of the armor plate now afloat at their mercy.

—*Scientific American*, December 5, 1896.

Trial of Cammell's 6-inch Plates.

We have reported many good results obtained with foreign armor during the past year. We are very glad to be able to give one herewith of an English plate tested on board *H. M. S. Nettle* at Portsmouth on September 22nd last. The plate was furnished by Messrs. Cammell. It is Harveyed steel, containing, among other elements, nickel. It measures 8 feet by 6 feet by 6 inches. The striking velocity is about 1,960 foot-seconds. The attack was with Holtzer's forged steel 6-inch projectiles, weighing 100 pounds each. The striking energy was, therefore, 2,665 foot-tons, and the calculated perforation by Tresidder's formula 13.45 inches of iron, giving a relation of 2.24 times the thickness of the plate attacked. Five blows were delivered. The plate completely defeated the attack of four blows, the point only getting through in one case, the projectiles having all broken up, leaving their heads embedded in the plate. There is a certain amount of cracking, as is to be expected, but the back of the plate, though bulged and cracked, compares very advantageously with that of a Krupp 5.75-inch plate, which we gave on January 31st, 1896, which had been exposed to attack by 15 and 21 cm. guns (5.95 inches and 8.27 inches) with velocities implying perforation by Tresidder's formula of from 10.2 inches to 13.6 inches of iron, that is, a relation of the actual plate of from 1.77 to 2.35 times its thickness. An intermediate blow, with a perforation of 12.6 inches of iron, or 2.19 times the thickness of the plate, had actually perforated, so that it may be said that Cammell's plate, so far as can be judged, has shown greater resistance to perforation than the very excellent plate referred to. The back of Cammell's plate shows more cracking, but this in plates of this thickness is of less importance than perforation. Taking it altogether, then, it must be said that this plate of Cammell's is the most encouraging result we have seen with English armor for some time past.

—*The Engineer*, January 22, 1897.

c. Powder and Explosives.

High Explosives and Smokeless Powders.

BY HUDSON MAXIM.

(*Concluded from page* 112.)

A NEW SMOKELESS POWDER.

Several years ago when smokeless powders were first being introduced, and competitive tests were being made mainly between them and the old forms of black and brown powders, it was easy to meet the ballistic requirements then imposed. Many changes, however, have taken place since then; the high ballistic results attained by recent smokeless powders, together with the knowledge gained from experience as to the vital importance of securing permanent stability of the nitro-compounds entering into their composition, have tended to place the present standard of excellence for a smokeless powder very high indeed. To be considered satisfactory to-day, a smokeless powder must have earned a reputation for stability, based upon tests severe enough to place that quality above question, and it must give ballistic results that were once deemed impossible.

Experience in the use of smokeless powders has developed many things not at first anticipated, and the knowledge from which have been evolved the best powders of the present time, has been costly of attainment. Formerly, the main object sought was to secure high ballistic results. The importance of effect of the gases of combustion upon the bore of the gun was not understood, but as powders containing very large percentages of nitro-glycerine were introduced, and many large and valuable pieces of ordnance were destroyed, the dangers arising from erosion were realized. At the present nothing less than a perfectly stable explosive compound, and one adaptable to guns of all sizes, and which will produce very high ballistic results and work a minimum injury upon the gun, will satisfy Government authorities.

The Maxim powder consists of about 90 per cent. pyroxlin or gun cotton; possessing a very high degree of nitration, with about 9 per cent. of nitro-glycerine, and from half to 1 per cent. of urea. It is a true colloid, being perfectly amorphous or structureless, and exceedingly hard and horn-like. The powder, which is made in relatively long cylinders, is perforated axially with a large number of small holes, so that a minimum of burning surface is presented to the initial flame of combustion, and a comparatively low initial pressure is secured. As in burning the perforations increase in diameter, the combustion surface and consequent evolvement of gases is greatly extended, so that the pressure is well maintained throughout the bore of the gun, and a maximum of propulsive energy is secured to accelerate the velocity of the projectile.

The products of combustion of gun-cotton, or tri-nitro-cellulose, are well known to consist mainly of carbonic oxide. The Maxim powder consisting, preferably, of nine-tenths gun-cotton, its products of combustion contain but little carbonic acid. Gun-cotton alone does not contain oxygen enough in its composition to cause it to ignite and burn with sufficient readiness to constitute a practical cannon powder when made into a dense colloid. It is, therefore, necessary to add a quantity of some nitro-compound richer in oxygen. Consequently nitro-glycerine, which is very rich in oxygen, and resolvable completely into gases, has been found the most suitable smokeless oxygen-bearing element that can be employed. Gun-cotton powders, made with an oxygen-bearing salt of a metallic base, such as nitrate of barium, are only a compromise between smoky and smokeless powders; from the explosion of such powders there remains as smoke, and as deposit to foul the gun, a quantity of carbonite about equal to the original amount of nitrate used, consequently such powders are but semi-smokeless.

The high velocities with comparatively low pressures that are obtained with smokeless powders, containing a large percentage of nitro-glycerine, are due to the large volume of gases and the enormous heat evolved by the nitro-glycerine in combustion. This great heat of combustion in connection with the high specific heat of the gaseous water produced, and forming a large percentage of the gases, gives the products of combustion of niro-glycerine a tremendous expansion power above that of any other ingredient that can be employed in a smokeless powder. This fact, coupled with the great increase in rapidity of combustion, as such a powder becomes heated in burning, has given ntiro-glycerine an excellent reputation as a constituent of smokeless powders from a ballistic standpoint. Furthermore, the ease and cheapness with which a colloid of gun-cotton containing large percentages of nitro-glycerine can be made, and the great difficulty and increased expense in making powder with a small percentage of it has caused nitro-glycerine to be used in excessive quantities, which has to a considerable degree counterbalanced the advantage due to its high ballistic value. The products of combustion of a smokeless powder containing a large percentage of nitro-glycerine have been found to be very erosive in their action on the bore of a gun. This is probably due to the great heat, density, and richness in oxygen of its gases. Such powders overheat a gun very quickly, and, consequently, powder containing a large percentage of nitro-glycerine, has the double disadvantage of greater density of gases and enormously greater heat. At the temperature of explosion of powder in a gun the elements of water produced in the reaction of explosions are dissociated, and exist as free hydrogen and free oxygen. Under the great heat and pressure it is probable that the oxygon in the carbonic acid gas, as well as the free oxygen, attacks the surface of the bore of the gun, and changes the character of the metal in immediate contact with the heated gases.

In the early smokeless powders, especially those made of compounds of soluble pyroxylin and nitro-glycerine, it was supposed that the nitro-glycerine actually held and retained the pyroxylin in solution, but it has since been proved that the nitro-glycerine is held by smokeless powders, whether made with high or low grade gun-cottons, in much the same manner as water is held by a sponge; in fact, the pyroxylin exists in smokeless powder in the shape of a very minute sponge-like substance, within the pores of which the nitro-glycerine is held in a free state. It is possible, even with powders containing as little as 25 per cent. of nitro-glycerine, to squeeze out the fluid in a pure state by subjecting a piece of the powder to great pressure between two smooth steel plates. Moreover, nitro-glycerine was formerly supposed to be practically a non-volatile substance, but it is now known that it evaporates, though slowly, at all temperatures. All fine-grained smokeless explosives, such as rifle and shot-gun powders, containing percentages of nitro-glycerine, lose a considerable weight on long exposure, owing to its fine state of division; and as the loss of a small percentage of nitro-glycerine will greatly affect the ballistic results of smokeless powders, this is a very important item to be considered. With cannon powders, which are made in large grains or blocks, exposing a comparatively small surface for evaporation, the disadvantages due to this cause are reduced to a minimum. The tendency to evaporate is also greatly reduced by lessening the percentage of nitro-glycerine employed.

TESTS OF SMOKELESS POWDER OF THE MAXIM POWDER AND TORPEDO COMPANY IN GUNS OF VARIOUS CALIBERS, AT SANDY HOOK, JUNE TO AUGUST, 1895.

Table I.—(5-in. Breech-loading Siege Rifle.)

Charge.	Projectile.	Velocity.	Pressure.
lbs.	lbs.	ft-secs.	lbs.
6	45	1,544	14,100
9	45	2,219	27,345
9¾	45	2,403	30,600

Government requirements for this gun:—Velocity 1,830 foot-seconds, with maximum pressure not greater than 31,360 lbs. per square inch.

Table II.—(8-in. Breech-loading Rifle.)

Charge.	Projectile.	Velocity.	Pressure.
lbs.	lbs.	ft-secs.	lbs.
55	300	1,977	29,808
57	299	2,019	32,148

Government requirements for this gun:—Velocity 2,000 foot-seconds, with maximum pressure not greater than 33,600 lbs. per square inch.

Table III.—(3.2-in. Breech-loading Field Gun.)

Charge.		Projectile.		Velocity.	Pressure-
lbs.	ozs.	lbs.	ozs.	ft-secs.	lbs.
1	7¼	16	8	1,617	29,600
1	7¼	16	8	1,615	29,400
1	7¼	16	8	1,617	29,491
1	7¼	16	8	1,617	29,033
1	7¼	16	8	1,611	29,067

Government requirements:—1,450 foot-seconds velocity; pressure not to exceed 30,000 lbs. per square inch; projectile 16 lbs. 8 ozs.

Table IV.—(10-in. Gun.)

Charge.	Projectile.	Velocity.	Pressure.
lbs.	lbs.	ft-secs.	lbs.
100	565	1,737	19,509
128	571	2,211	34,506

Government requirements for brown prismatic powder for this gun are as follows:—Charge, 250 lbs.; projectile, 575 lbs.; velocity, 1,975 foot-seconds; pressure, 37,000 lbs. per square inch.

Table V.—7-in. Howitzer.

Charge.	Projectile.	Velocity.	Pressure.
lbs.	lbs.	ft-secs.	lbs.
2½	105	700	7,000
3¾	105	914	less than 14,000
4½	105	1,059	14,200
4¾	105	1,059	15,500
4¾	105	1,102	15,212
4¾	105	1,002	15,077
4¾	105	1,089	14,200
4¾	125	1,040	16,000
4¾	125	1,044	16,069
5	125	1,074	17,629
5	125	1,076	17,619

Government requirements for this gun:—1,060 foot-seconds, with 125 lb. projectile. Pressure not to exceed 26.880 lbs. per square inch.

Table VI.—12-in. Sea-coast Gun.

Charge.	Projectile.	Velocity.	Pressure.
lbs.	lbs.	ft-secs.	lbs.
130	1,004	1,542	15,285
——	——	——	15,737
174	1,002	1,847	22,000
200	1,002	2,047	28,700
220	1,002	2,204	36,000

No objection can be sustained, on this account, against cannon powders containing a low percentage of nitro-glycerine.

You will observe by these tables of results of firing of Maxim powder at the Sandy Hook proving grounds, in the United States, that the velocities are remarkable for comparatively low pressures, when like charges are used.

The results were obtained with the first samples of the powder tried in the respective guns, without any preliminary firing, to determine the best forms adapted to different calibers. These velocities were obtained with the shorter guns of the army; and higher results are reasonably to be expected in the longer naval guns. In examining these very interesting tables, it must be remembered that the Maxim smokeless powder contains only 9 per cent. of nitro-glycerine; and that the only ballistic results heretofore obtained that are comparable with these results have been secured by the use of smokeless powders containing from 50 to 70 per cent. of nitro-glycerine. Probably the most remarkable result obtained with the Maxim powder is that with the 5-inch breech-loading siege gun. The Government requirements for this gun were a velocity of 1,830 foot-seconds, with a maximum pressure of 31,360 lbs. per square inch. The Maxim powder gave a velocity of 2,403 foot-seconds, with a pressure of only 30,600 lbs., or less than $13\frac{7}{10}$ tons. This beat the Government requirements about 5 to 3. The 7-inch Howitzer gave a velocity equal to the Government requirement, with a pressure of little more than half of that officially allowed for producing it. The results of firing the 3.2-inch gun are also very interesting; they were the outcome of some experiments made with the powder chamber shortened by a plug in the breech, and with every cubic inch of space in the powder chamber filled with powder. It was not sought to obtain a pressure less than 30,000 lbs., nor a velocity greater than 1,450 foot-seconds. With such density of loading the velocities for the pressures are very good, and the uniformity in both velocities and pressures is remarkable.

The difficulties hitherto encountered in the manufacture of a smokeless powder for large guns in the form of a colloid, consisting chiefly of gun-cotton of the highest degree of nitration, known as tri-nitro-cellulose, have been removed by our processes; and the high ballistic results, heretofore thought obtainable only with a compound containing from 50 to 70 per cent. of nitro-glycerine, have been exceeded by a compound containing only 9 per cent. of nitro-glycerine.

—*Industries and Iron*, May 22, 1896.

Von Förster Smokeless Powder.

The powder works of Max von Förster, office in Berlin, publish in the *Deutsche Heeres-Zeitung* the results of experiments with a smokeless military powder, consisting of gelatinized and dried gun-cotton in the form of small thin leaflets, the raw material from which it is made being ordinary fibrous cotton.

The chemical properties of this powder give a sufficient guarantee for its permanence in any climate; the ballistic results are good for every small arm caliber, as shown by the following table:

Caliber of gun. mm.	Weight of projectile. grm.	Velocity at 25 m. m.	Gas pressure in atmospheres.
7.9	14.7	624	2985
7.65	13.7	635	3058
7.0	11.2	700	2980
11.0	25.0	420	1325

The firing records are good, especially that of 7 mm. caliber.

The powder for large caliber arms with leaden projectiles offers the possibility, under circumstances where supplies of old arms are to be utilized, of securing for such arms the advantage of smokeless fire, thus giving them a very material part of the advantages of the new guns, without any outlay other than that required to procure this powder. The powder for calibers 7, 9 and 7.65 meets the requirements, while the powder for 7 mm., in spite of the small caliber, gives a relatively low gas pressure, making possible a regular action of the arm, and also a considerable velocity, viz: 700 meters.

The works also furnish smokeless powder in leaflets and cubes for cannon, and have guns for testing purposes in their establishment.

GENERAL MILITARY MATTERS.

The Application of Photography to Surveying.

The first practical application of photography, on this continent, to the continuous survey of large areas, is due to the experiments and patient and intelligent work of Mr. E. Deville, Surveyor General of Canada. This method of obtaining topographical data was first suggested in 1850, by Colonel Laussedat, of the French army; and later, German and Italian engineers continued his investigations and elaborated upon his methods. But the system seems to have been entirely abandoned in France, and in Germany it is mainly used for making plans of buildings; but the Italians have instituted the Ordnance Photographic Survey, and under the able engineer M. Porro, they have vastly developed the system and have done some remarkable work. In America, Lieutenant Henry A. Reid, U. S. A., has published an excellent work upon "Photography Applied to Surveying," in which he gives the detailed history of the process and describes the instruments and methods employed. But the Canadians, alone on this continent, have made a practical application of the system upon any extensive scale.

Until a few years ago the land surveys of the Dominion Government were chiefly confined to the prairies of Manitoba and the Northwest Territories, where the operations were simple and topographical features were scarce. But when these surveys reached the rocky mountains the conditions changed; topography became well marked, and the old system of section lines became useless, if not impossible in application. Government administrations demanded a fairly accurate map and some means had to be devised for making this map rapidly and at a moderate cost. As the ordinary methods of topographical surveying were too slow and expensive, and as rapid surveys, based upon triangulation and sketches had been tried and proved ineffectual, photography was resorted to.

The principle of the method employed and a summary of work actually performed in the Dominion is given by Mr. John S. Dennis, of Ottawa, Canada, in a paper read before the Denver meeting of the American Society of Irrigation Engineers. From this paper we make the following abstract:

"The method used is based upon the fact that a photograph taken with a suitable lens is a true perspective, in which the focal length is the distance line. By drawing the horizon and principal lines all measurements usually taken on the ground can be obtained from the photograph. But there is this difference, that while the ordinary surveying instruments and methods restrict the surveyor to a few constructions, photography affords a great variety of processes by applying the inverse laws of perspective. Mr. Dennis does not enter into the detail of the methods used, and refers those interested to the work of Lieutenant Reid; but he gives the result of the surveys thus made. Regular photographic surveys were commenced in 1888, in the main range of the Rocky mountains, near the Canadian Pacific Railway, and 250 square miles were covered in that year. From that time from 375 to 500 square miles were thus surveyed each year until the aggregate area covered, at the end of 1892, was 2,025 square miles.

These surveys were all made by a party consisting of the topographer, one assistant, a packer and a laborer. It has now been established that 500 square miles is about the limit of area which a party, travelling rapidly, can cover in one season; though this area is, of course, affected by the general character of the ground; being largest in an open district with wide undulations. The topographer does not need more than a few minutes at each station, to observe angles and expose his plates. As showing the general advantages and the rapidity of the work, the season of 1892 is taken as follows: The start was made on June 29, the snow being too deep for work before that date, and the survey was stopped on October 17th, when the snow again became too deep for travelling. Of the 111 intervening days, 48 were lost through smoke, rain and snow storms; in the 63 actual working days thus left, the equivalent of 500 square miles of territory was surveyed, an average of 8 square miles per working day.

The results of the survey are plotted on a scale of 1-20,000, and reduced for publication to 1-40,000. The published "Anthracite" sheet, with an area of 63 square miles, may be taken as an illustration of practice. This plot was made from 6 stations inside the sheet and 11 stations outside, and 1,075 points were fixed by intersections, or by constructions equivalent in accuracy, taken from 35 photographic views. This corresponds to 17 points per square mile; though more points could be fixed without difficulty as the limit is the time which can be devoted to plotting. The office rule is that the topographer must plot his season's work before going into the field again; though more detailed maps of any particular locality can be made at any time from the same photographs. The expenses of the season of 1892 were:

Packer, $2.00 per day; laborer, $1.50 per day	$429.00
Transportation	578.50
Living expenses	394 71
Miscellaneous	76.98
Total	$1,479.19

To this add $1,500 per annum for the salary of the topographer and $730 for that of his assistant, and the total is $3,709.19, as the cost of surveying 500 square miles in one year. This is equivalent to $7.42 per square mile, or 1.15 cents per acre. This extremely low cost is due to the fact that the party is very small, and very little time is consumed in taking angles and photographs, and no time is required in taking measurements on the ground. The time spent in the field is chiefly devoted to travelling from one point to another, and the actual work of deducing results from the data thus collected is done in the office by two men.

—*Engineering News*, November 19, 1896.

Shorthand in the Army.[*]

A paper on the above subject was read by Captain J. E. Caunter, 2nd battalion the Welsh Regiment, at the Royal United Service Institution on Wednesday last. Major-General Lord Methuen, C. B., C. M. G., Commanding the Home District, was in the chair.

After insisting that, while many non-commissioned officers and men have taken the advantage of the opportunities offered them by the establishment of classes in some of our larger garrison towns to qualify as shorthand clerks, the full value of shorthand could not be obtained until officers also make themselves proficient in the system. Captain Caunter continued:

In the Queen's Regulations, we find it stated that "a knowledge of shorthand is of great advantage to a staff officer," and that those who obtain a certificate of proficiency in it will have their names recorded. It is a matter of satisfaction that the utility of shorthand for army purposes has thus received official recognition, but it should be remembered that an officer must necessarily devote a good deal of time and some expense, in order to obtain a thorough knowledge of shorthand; and, therefore, some further inducement should be held out to them to qualify. I would, therefore, suggest that shorthand should be introduced as an extra subject at the entrance examination to the Staff College; and that opportunities should be given at the Royal Military Academy and at the Royal Military and Staff Colleges, for those who may wish to do so, to make themselves proficient in the system. What a boon it would be to the student at the Staff College to be able, if necessary, to take down his course of lectures verbatim, instead of jotting down a few disjointed sentences in cumbrous longhand!

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[*] An excellent course in shorthand has recently been published in the New York *Tribune* by *A. S. White, Esq*, care *The Tribune*, New York City, which we can heartily recommend as simple and easy to acquire. We took the course ourselves and found it not only good in itself but taught in a rational way that attracted and interested one. Mr. White is still giving instruction in this subject.—Ed.

Shorthand will lose 90% of its value unless it is distinctly understood that all military shorthand writers must be trained in the same system, so that they may be able to read and transcribe each others' notes. With the staff officer and his clerks proficient in phonography the chief would dictate his views, which the staff officer would take down expeditiously in shorthand, pass to the clerks, who would at once transcribe in proper letter form, and by the time other correspondence was disposed of, this and other letters in quick succession would be ready for the chief's signature. Then, again, a staff officer has frequently to deal with matters of a confidential or semi-confidential nature, which must necessarily pass through his hands alone—such, for example, as the preparation of defense schemes and confidential reports, etc., and in making his rough copies a knowledge of shorthand would certainly save him many hours a week. When attending his chief at inspections, official visits, interviews, etc., he is constantly called upon to make notes of various points on which, later, reports have to be rendered, and in such cases the few notes he is at present able to take down in longhand are often totally inadequate. Again, what a saving of time would result in taking down the proceedings of courts-martial, courts of inquiry, boards, etc., in shorthand! The small space occupied by shorthand characters, in comparison with those employed in longhand, may be utilized in military sketching. With the small phonetic characters this drawback can to a great extent be obviated, so that without endangering the clearness or obliterating the detail, we can show much on the sketch which would otherwise have to be embodied in a separate report. This peculiarity may also be taken advantage of in making use of the pigeon post, and the necessity of reducing the despatch first by means of photography be dispensed with. No less than 21,000 have been written in phonography on an ordinary half-penny post-card.

The importance of the acquisition of a thorough knowledge of modern languages by officers is so well recognized, that it may not be out of place in a paper dealing with phonography, to mention that the system has been used with marked success in teaching these subjects. The fact that by its aid we are able to commit sounds to paper with absolute fidelity, has been utilized to overcome the difficulties of pronunciation. Mr. William Pryor, who has done so much for shorthand in the army, by the formation and instruction of classes for N. C. O.'s and men quartered at Plymouth and Devonport, whilst on a recent visit to some friends in France, took down at their dictation several passages in French, and some days later, although understanding little or nothing of what he had written, read back his notes with such accuracy of pronunciation that his hearers had no difficulty in following the sense of his words.

In the field, the employment of phonography would be even more valuable than in the office. The importance of saving every minute on active service, and of the speedy transmission of orders and reports, can hardly be exaggerated. The advantage of sending written orders in place of verbal orders is generally acknowledged; yet the length of time necessary to put the former on paper frequently causes the employment of the latter. Written orders would not only be always possible, but would be invariably employed if our staff officers possessed a knowledge of shorthand, for it would take no more time to write an order than to give a verbal one.

Moltke has declared that "shorthand is indispensible for an army." Continental armies are utilizing it for military purposes. With these examples before us, it is surely time that we, too, should endeavor to reap the benefits which would assuredly follow its general introduction into the service.

—*Unitied Service Gazette*, January 30, 1897.

RANGE TABLE FOR 10″ B. L. RIFLE.

Practice Charge 205 lbs., B. P. Powder. Projectile 575 lbs. Initial Velocity 1725 foot seconds.

COMPUTED BY FIRST LIEUTENANT ALFRED M. HUNTER, FOURTH ARTILLERY.

Range, yards.	Angle of elevation, φ.	a	∓ Δ φ for Δ V = ± 50 F.S.	∓ Δ φ for Δ C = ± $\frac{1}{10}$.	Drift, yards.	Deviation R. or L. for 10 miles of cross wind. yds.	Angle of fall.	Time of flight, seconds.	Remaining velocity. F.S.	Maximum ordinate. Feet.
6000	7° 28′.6	9′.7	25′.4	13′.4	17.8	10.9	9° 38′.6	12.9	1178.1	676
6100	7° 38′.3	9′.8	26′.0	13′.9	18.5	11.3	9° 52′.5	13.15	1171.6	706
6200	7° 48′.1	9′.9	26′.6	14′.5	19.2	11.7	10° 6′.8	13.43	1164.7	736
6300	7° 58′.0	10′.1	27′.2	15′.1	20.0	12.1	10° 22′.1	13.69	1159.0	765
6400	8° 08′.1	10′.2	27′.8	15′.7	20.8	12.5	10° 37′.8	13.96	1153.8	793
6500	8° 18′.3	10′.4	28′.5	16′.3	21.8	12.9	10° 52′.4	14.21	1148.6	828
6600	8° 28′.7	10′.5	29′.2	16′.9	22.6	13.3	11° 8′.4	14.49	1143.7	860
6700	8° 39′.2	10′.6	29′.8	17′.5	23.4	13.7	11° 25′.1	14.77	1136.9	891
6800	8° 49′.8	10′.7	30′.6	18′.2	24.3	14.2	11° 41′.4	15.08	1130.9	924
6900	9° 00′.5	10′.8	31′.3	18′.9	25.2	14.6	11° 58′.1	15.32	1125.9	964
7000	9° 11′.3	10′.9	32′.0	19′.6	26.2	15.1	12° 14′.3	15.60	1121.6	1005
7100	9° 22′.2	11′.0	32′.7	20′.3	27.2	15.5	12° 31′.3	15.88	1116.3	1034
7200	9° 33′.2	11′.1	33′.5	20′.9	28.2	16.0	12° 48′.5	16.16	1111.8	1074
7300	9° 44′.3	11′.1	34′.3	21′.4	29.3	16.5	13° 5′.5	16.45	1106.3	1113
7400	9° 55′.4	11′.2	35′.1	22′.3	30.4	16.9	13° 24′.2	16.72	1102.2	1151
7500	10° 6′.6		36′.0	23′.3	31.5	17.4	13° 39′.6	17.00	1097.8	1184

The angles of departure are corrected for the altitude of the trajectory.

BOOK REVIEWS.

Life of Napoleon Bonaparte, by William Milligan Sloane, Ph. D., L. H. D., Professor of History in Princeton University. Volume II, New York: The Century Co., 1896. Complete in four volumes, per volume, cloth, $7.00; half morocco, $8.00; three-quarter morocco, $9.00; full morocco, $12.50.

Professor Sloane's great life of Napoleon, so magnificently clothed by the publishers, is the most accurate, impartial, thorough and complete life of Napoleon that has yet appeared; it ranks as the best historical work produced in America of late years, and places the author in the foremost rank of American historians.

The first volume covered the period from Napoleon's birth to include the fall of Venice in 1797. The early life of this representative man of the epoch which ushered in the nineteeth century is there for the first time portrayed with a faithfullness such that his character in later life is no longer a great enigma. After a brief introduction on the condition of Corsica at the time of Napoleon's birth, and an interesting account of the Bonapartes in Corsica, the *life* of Napoleon himself opens, and we are surprised at the outset with the mass of new matter which the author has collected and the clear views which he has arrived at on points formerly obscure and doubtful.

The second volume describes the growth of Napoleon's power from his rescue of the Directory in 1797 to the rout of the Prussian army at Auerstädt in 1806. In this period are included Marengo, Ulm, Austerlitz, Jena and Auerstädt; the rescue of the directory, its overthrow, Bonaparte First Consul, then Life Consul, then Emperor. Throughout, the author keeps before us the *man*, his feelings, his hopes, his ambitions, whether it be as statesman or as soldier. The campaigns and battles are described in broad outline for the general reader, but their true significance is set forth in clear and incisive language.

Of Marengo he says: "A successful battle disorganizes an opposing army, but successful strategy entirely destroys its power. When will and deed accompany each other the result is conclusive. The victory at Marengo was such a decision. Bonaparte the army commander lost it; Bonaparte the general-in-chief won it, exactly as it was. Marengo was the pattern of an offensive campaign organized, not to win battles and spare the lives of soldiers, but to destroy an enemy."

At the time of the campaign of Ulm we have the following picture of the men about the great leader:

"In order to apprehend Napoleon's supernal greatness it is essential at this period of his life to shut out of view the politician, and fix the eye again on the general; to see him, moreover, solely as a strategist. It may be said that he was for the first and last time unhampered. His army was the best in Europe, composed of young and well-drilled conscripts, who had been eighteen months under arms, with a large nucleus of trained veterans. Of the generals who commanded the seven corps destined for Germany only two, Augereau and Bernadotte, were over forty years of age. The Emperor himself, Soult, Lannes, and Ney were thirty-six, Davout was thirty-five, and

Marmont only thirty-one. Of the division commanders one half were between thirty and forty, while only a single one was fifty. Not one of these men were commonplace."

The sun of Austerlitz looked down on scenes like these:

"Napoleon advanced to observe the conflict, and a little before eleven, at the critical moment, when the regiment of his brother Joseph was on the verge of being engulfed and lost, he threw in the cavalry of his own guard, under Bessières and Rapp, upon the Russian guard, turned the scale against them, and with his own eyes saw Constantine withdraw. The Russian vanguard under Bagration had meantime come in from Bosenitz, and was hotly engaged with a portion of the French left. The entire cavalry mass of Lichtenstein and Murat was commingled in the bitter conflict. With the retreat of Constantine began the rout of the whole Austro-Russian right wing."

The volume closes with another campaign of marching: the war with Prussia, in which "Napoleon's preparations were better than any hitherto made, and his strategic plan was one of the greatest conceptions so far formed by a master in that department of military science."

We have endeavored to give some little idea of the author's power of description and of his literary style, but of the beauty of the illustrations we can give no adequate conception; in this respect each succeeding volume surpasses the preceding. Among the most striking of these may be mentioned Gérôme's picture of Bonaparte before the sphinx, Detaille's Bonaparte in Egypt, Myrbach's Tivoli Garden in Cairo and Napoleon at Austerlitz, Iselin's and Guillaume's busts of Napoleon, Prud'hon's Josephine, Meissonier's Moreau and his chief of staff, Chartier's Murat leading the cavalry at Jena, Girordet's Napoleon received by the monks on Mount Saint Bernard, and Boutigny's meeting of Napoleon and Mack.

This volume, like the first, is a work of art in every respect,—in illustrations, in printing and in binding, and the author must be well pleased to be so splendidly seconded by the publishers.

J. P. W.

Tratado de Balistica Interior por D. Onofre Mata y Maneja teniente coronel de artilleria. Segunda Ediciốn. Corregida y aumentada. Madrid: Imprenta del Cuerpo de Artilleria, 1896. Pp. 297.

The first edition of this work appeared in 1890 and met with deserved success in Spanish speaking countries. The second edition, as it lies before us, has been considerably increased. In its present form, the work consists of three parts. The first treats more or less generally, of powders in respect of their composition and decomposition, of the formation of powder gases and of the influence of the pressure of the surrounding medium upon combustion. In a word, this part gives the usual applications of thermochemical and thermodynamical laws to interior ballistics, and is therefore not unlike similar portions of other text-books of interior ballistics. When we reach Part II, however, we tread on virgin ground, in so far as treatment is concerned. The author gives us here a new solution of the fundamental problem of interior ballistics. Taking Marriotte's law for granted, and assuming that the velocity of combustion is directly proportional to the pressure in which combustion takes place, and that combustion proceeds in a direction normal to the surface of grain, and introducing a new idea, that of the specific velocity of combustion, the author eventually writes out the differential equation of the motion of the projectile in the bore, in terms of the thickness of the grain consumed. To this equation, after complete integration under a finite and definitive form, the remainder of the text is practically devoted, applications being made to the various problems that come up in gun-building and in gun-proving. It surely is noteworthy that we have here a text-book, in which for given conditions, the solution reached is direct and final. This part closes with a very general description of the usual ballistic instruments. Part III, consists of applications to actual cases, Spanish guns and Spanish powders being considered. These applications add to the value of the work as a text-book, and they also serve to measure our confidence in the method itself. In regard to the latter point we need only say that in the great majority of cases, the errors fall well within allowable limits, the computed and the measured values of both pressures and velocities being found as a rule in more than substantial agreement.

Colonel Mata has made a positive addition to the subject on which he writes, and his book may be justly regarded as one of great importance. His investigation is characterised by simplicity and completeness and its applications by directness. Nor should we pass over in silence the clearness of the style,—a quality undeniably as desirable in a scientific text, as in any merely literary effort. The get-up of the book is worthy of its professional excellence; the paper is good, the type clear and bold, and the equations stand out.

We venture to hope that a translation of Colonel Mata's book may be made for the benefit of our service.

C.DeW.W.

Kriegsgeschichtliche Beispiele ans dem deutsch-französischen Kriege von 1870-71. By Hermann Kunz (Major, retired). Parts I and II. Berlin: Mittler & Sohn. 1897. 1.50 to 2.25 marks (38 to 57 cents) per part.

The new spirit in military literature aims to present books of use to the officers serving in the field, *at the front*, as the Germans express it, to address not as of old the army commander, but the subordinate officer, to discuss no longer *strategy*, but *tactics*.

The present contribution is written in this spirit and has set for itself the praiseworthy object of making the study of military history attractive to the young officer, easy and interesting. Every important battle of the Franco-German war is carefully studied, analyzed and discussed. Each part as it is issued is complete in itself, at the same time the entire work forms a homogeneous and connected whole.

The first two parts treat of *night combats*, which, according to the tacticians, have become of such enormous importance, on account of the increased range, rapidity of fire and flatness of trajectory of modern fire-arms. Front attacks will be exceedingly difficult, and many believe that in most cases it will be necessary to attempt them only under cover of darkness, especially against a strong defensive position.

Part I takes up the *night battle* on the plateau of Moscow Ferme and Point du Jour on the 18th of August, 1870. After a careful statement of the movements, based on the German official work, the various regimental histories, the French histories and other available authorities, the author gives his conclusions, which are exceedingly interesting. We can quote only a few sentences:

"What did the First German Army accomplish in the night battle of August eighteenth? What was the result of the ten hours struggle? What was the return for the immense sacrifice of life on the part of the Germans?

"The answer is not very satisfactory,—in not a single point was the French position pierced."

"According to the most careful computation, the losses stood 5,300 for the Germans as against 2,700 for the French. But the matter becomes much more interesting if we subtract the losses on both sides in the Bois des Genivaux. Here the conditions were about the same for both, and the combat was conducted at such short ranges that the superiority of the chassepot did not come into play."

Calculation gives a loss of 700 French and 800 German, hence, for the rest of the battle, 4,500 Germans and 2,000 French. Now, considering the excellent effect of the Prussian shrapnel fire, the author shows that at least 1,200 of the killed and wounded must be ascribed to it, leaving but 800 due to the fire of the small-arm, whereas the poorer French artillery fire, which was silenced early in the fight, could hardly claim more than 300 killed and wounded. This leaves 800 French as against 4,200 Germans killed by infantry fire!

His final conclusion then is:

"Night combats are still dangerous. There are situations in which we are compelled to choose the lesser of two evils, and that may occasionally be the night combat. Therefore, the latter must be regarded as a necessary evil, but let us not look upon it as a radical means of overcoming the greatest difficulties with ease and certainty."

Part II describes a series of night combats, in August, September and October, 1870, each one of which is a careful tactical study in itself.

The maps accompanying these two numbers are excellent.

The work must be regarded as one of the best contributions to the domain of *tactics* that has appeared of late years. The questions it discusses are the great tactical questions of the day, the views taken are bold and independent, and the conclusions are convincing.

The author proposes to continue the series with essays relating to the attack and defense of villages, woods and fortified positions, to surprises, flank attacks on infantry, completing his work by illustrations from the Turko-Russian as well as the later wars.

J. P. W.

Aluminium: Its history, occurrence, properties, metallurgy and applications, including its alloys. Joseph W. Richards, A.C., Ph.D., Instructor in metallurgy at the Lehigh University. Third Edition, revised and enlarged. Philadelphia: Henry Carey Baird &Co. 1896. Price $6.00, by mail, free of postage to any address in the world.

A systematic treatise on aluminum presenting the subject in its entirety, furnishing *all* the reliable information about this important metal, is certainly a timely contribution to the general information of the world at large, while the recent applications of aluminium, as well as the promises of its future utility, render it of great importance to the military world.

The first chapter treats of the history of this metal, and it is interesting to note that one of the earliest applications suggested by its qualities was a military one:

"After reading this paper, Deville caused a medal of aluminium to be struck, which he presented to the Emperor Napoleon III. The latter, looking forward to applying such a light metal to the armor and helmets of the French Cuirassiers, immediately authorized experiments to be continued at his own expense on a large scale. * * * The first article made of aluminium was, in compliment to the Emperor, a baby-rattle for the infant Prince Imperial."

The growth of the aluminium industry is one of the most remarkable in history; in 1883 the United States produced only 70 lbs., in 1894 its total production rose to 706,000 lbs., nearly one-third the world's product. The price of aluminium in the spring of 1856 was $90.90 per pound, in the fall (due to Deville's experiments) it fell to $27.27 a pound, and since then it has been gradually falling to its present market price of $0.35.

The occurrence of aluminium in nature is interesting to us mainly on account of the two principal sources of the metal, viz: *bauxite*, the hydrous aluminium oxide, and *cryolite*, the aluminium-sodium fluoride. The author then discusses the physical and chemical properties of the metal, and the properties and preparation of its compounds, in a manner at once clear and thorough. Its physical properties depending largely on its purity, a number of analyses of specimens prepared by the different processes are given and add much of value to the chapter on the subject.

Until recently sodium was as essential in the reduction of aluminium ore as the ore itself, and it is so bound up with the history of this metal that, although it is not at present used in aluminium reduction processes, a very carefully prepared chapter treats of the manufacture of this auxiliary metal, with special reference to the latest processes (Castner's, 1886 and Netto's, 1887, as well as the reduction of sodium compounds by electricity).

The rest of the work, about two-thirds, is devoted to the reduction of aluminium compounds, the working of the metal and the preparation of its alloys.

The most successful process to-day appears to be the Héroult-Kiliani process used at the Neuhausen works in Switzerland, which consists in reducing alumina between carbon poles under an electric current of 7500 amperes at a tension of 55 volts.

"This plant, working to its full capacity since the middle of 1893, turns out daily 2500 kilos (5500 pounds) of aluminium, equal to 900 metric tons a year.

"The cost of No. 1 aluminium is at present about 1.50 francs per kilo, or 23 cents per pound. One of the officers of the company is quoted as saying that they could make No. 1 aluminium for 2 francs (less than 20 cents per pound) if working a plant producing 10,000 kilos per day. A plant of such a size is one of the possibilities of the next five years."

The work closes with a summary of the best methods for the analysis of commercial aluminium and the aluminium alloys, in which field the author has done an immense amount of work, and he is to-day one of the highest authorities on the subject in this country.

The applications of aluminium are growing every day. Its military uses are already numerous,—canteens, cooking-utensils, pontoons, lace for embroidery, ammunition wagons with aluminium frames, bicycles, reflectors for search lights, instruments of all kinds, field glasses, compasses, name-tags on carrier pigeons, etc.,—but it is difficult to say what the cheapening of the metal may not bring forth for the future.

The entire work is well worth careful reading and study, not only on account of the general information it contains in regard to a metal which has recently became one of the common metals of everyday life, but also on account of the undeveloped future of this metal that promises so much for the military world as well as the world at large.

J.P.W.

Mémoires de Louis-Auguste Le Pelletier, 1696-1769. Paris: Librairie Hachette et Cie, 1896. 5 francs.

Louis-Auguste Le Pelletier belonged to a family of artillery officers, and these *mémoires* comprise those of his brother, of his father and of his grandfather, as well as his own. The period covered is from Louis XIII nearly to Louis XVI, and contains much interesting matter on the organization of the army, and more especially of the *corps of artillery.*

In a general preface by the editor is given a history of the changes that have taken place in the organization of the French artillery; this is followed by the author's account of the services of his grandfather, Michel Le Pelletier (1614-1689), who rose to the rank of *garde général de l'artillerie* in 1662, and took part in seventy-five sieges and ten battles; the campaigns of his father (1655-1714) are outlined next, and his having been present at twenty-nine sieges and five battles, and attaining the rank of lieutenant-general of artillery, are sufficient to indicate the importance of his work and life.

The author himself was born in 1696, and at the age of 15 days the Duke of Maine inscribed his name as one of the 101 privileged to enter the artillery corps. In 1705, at the age of nine, he was appointed ensign, and followed his father and the army from post to post, receiving instruction from various ecclesiastics until 1713, when the general peace gave him and his brother an opportunity to complete their studies at college.

In 1720 he went to the artillery school at La Fère, and he gives us a very interesting chapter on the methods of instruction then in vogue and on the life there. After a tour of garrison duty at Ham and Saint-Quentin, he married in 1730 Marie Maresse. He remarks on this subject: "I was then *commissaire ordinaire* and our fortunes were not very brilliant or promising." In the following year he was ordered to command (*en troisième*) the artillery school at Grenoble, and in 1732 he became commandant (*en second*) of the school of Besançon.

He took part in the campaigns in Italy in 1733 and 1734, and furnishes some droll sketches of the officers in command, as well as interesting accounts of the sieges of Pizzighettone and Milan. His last service in Italy at this time was at the 'battle of Parma, after which he joined the army at Strasburg, where he commanded 120 pieces and 2,700 artillery horses, but saw little active service as he remained in the camp of Dalheim during the campaign.

In 1739 he was ordered to Corsica as second in command of the artillery, and the unsettled condition of the island, and the fierce character of the insurrection is graphically set forth. In 1740 he was promoted to the rank of colonel. All this time he was carried as second in command at Grenoble, but in the following year he was replaced there and assigned to the command of the department of Cambray.

The war of the Austrian succession (1744) found him in the field again, doing excellent service in the sieges of Menin, La Quenocque, Furnes Friburg, Antwerp and Namur. In the fall of 1744 he was made *brigadier*, and in 1746 he was assigned to the command (in chief) of the artillery school at Grenoble, and in 1749 to that of La Fère also.

In the campaign of 1759 he formed part of the army of the army of the lower Rhine and reached the rank of lieutenant-general in 1761.

While the greater part of the volume is devoted to military events, there are also portrayed some reminiscences and experiences of a more general character, as well as the characters of marshals, generals and others; and reflections on the manners and customs of a time not generally very well known are occasionally interspersed.

A brief account of the services of his brother, Michel-Laurent Le Chevalier Le Pelletier (1697-1765), who also rose to the rank of lieutenant-general, closes the memoirs proper, and an appendix of extracts from the archives of baron Le Pelletier closes the work.

The book is printed on heavy paper, and illustrated with five portraits. It lacks the charm and intense personal interest of the best of the French memoirs, but its value lies in the fact that it relates to a time not very well known, and to a branch of the service that was preparing itself for the work required of it by the great Napoleon.

J. P. W.

The Service of Security and Information, by Arthur L. Wagner, Captain Sixth Regiment of Infantry, Instructor in the Art of War at the U. S. Infantry and Cavalry School. Fourth edition. 1896. Kansas City: Hudson Kimberly Publishing Co.

The credit due to Major A. L. Wagner (lately appointed Assistant-Adjutant-General) for his work in the domain of tactics is gratefully acknowledged by his brother officers, and must not be forgotten in a review of his work. Before he published the first edition of his "Security and Information" we had nothing that was standard for us, and to most of us only the English works (excellent in themselves, but not directly applicable to our organization), or English translations of continental tactics, were accessible.

His "Service of Security and Information" at once placed us on an equal footing with other armies in this respect, and the value of the work is shown by the rapidity with which a knowledge of its subject-matter has been disseminated through the army and the national guard since its appearance.

It stands to-day as the best complete treatise on the subject, and well deserves to be the text-book officially adopted for the examination of officers for promotion. Although necessarily largely a compilation, it is based on a careful study of practice at home in our late war and in our Indian campaigns, as well as of theory and of practice abroad.

There are a few points, however, which we would like to call attention to, and which could readily be changed to the great advantage of the book.

The first of these is the *advance guard* and *rear guard drill*: a *drill* for such a purpose seems to us entirely out of place.

The second relates to the questions in the back part of the book. Some of them are evidently framed for the school-boy method of committing the text to memory and remembering its particular wording in every case. For example, take question 4. "The information necessary for a commander is of what two kinds?" Now, there are several correct answers that may be given to this, and the highest authority on tactics might fail to give the one desired. The same objection obtains with reference to the rest of the questions on that page. There are several others, too, quite as poorly worded: "37. What should the commander of the advance guard continually consider, and what, in general, should he do?" It is not necessary that every little point in the text should be brought out by a direct question; questions a little more general in character often bring out the real knowledge of the student much better. If any one will look up the answer to question "349. How may a spy often be detected?" he will see what is meant.

A little care in the framing of the questions will readily remedy this matter, and that it can be done is proved by the excellent set of questions, almost perfect in their wording, which have been proposed to accompany "Root's *Military Topography and Sketching.*"

There are also a few minor points that seem to require attention, for example, in establishing Cossack posts (pp. 101-2) why assemble by squads and then make 3 and 4 (front and rear rank) march to the left to their proper place, --why not assemble by half squads? Certainly, no officer in the field would make his men march an unnecessary step in order to conform to the *letter* of the drill regulations, when the *spirit* of the latter is so evidently opposed.

The defense of an outpost (p. 104) is not clearly presented, for the reason that the two cases arising are: (1) the army is strategically *advancing* or *stationary*, (2) the army is strategically *retreating*. Of course, in both cases we assume it to be temporarily at a halt; but in the first case what the author states in the second paragraph on p. 104 would not be correct, in general. With an army strategically advancing the infantry of the outposts *would* pursue, but of course within the limits that would hold good in any engagement: the object in this case is to *give* battle and not to avoid it.

We have been thus critical because we are all interested in every word of the text not only for our own information, but also as a text-book that we are to teach and be examined upon, and which must be so clear and definite that every private soldier can fully comprehend its exact meaning. All that we find fault with are matters of detail and do not affect the general excellence of the subject-matter of the book.

J. P. W.

Aide-Mémoire de l'officier de Marine pour 1897, by Edward Durassier, Chef de bureau au Ministère de la Marine, and Charles Valentino, ancien officier de Marine, Chef de bureau au Ministère de Marine. 10th year. Paris, Henri Charles-Lavauzelle, Editeur militaire. 11 Place Saint-André-des-Arts. Pp. xxi, 846. Price 5 francs.

In view of the constant increase in naval strength amongst the various countries of the world, it becomes more and more important not only for naval officers but also for those who are interested in the organization of military forces, to take note of the progress made in naval art both at home and abroad, to have a knowledge of the comparative value of the different fleets of the world and to mark their preparedness for war.

This work, appearing regularly in January each year, gives in a very concise manner most valuable information on all the modern navies. An introductory table gives one at a glance the number and kind of modern war vessels ready for action belonging to the different nations, also those which have been recently launched and are undergoing trial.

Our attention is particularly attracted, however, by the chapters relating to the naval personnel, warships and marine artillery of all the different countries. These chapters give concise information on organization; complete data on systems of construction, motive power and offensive and defensive power of the several types of warships of each nation; and also on the construction, breech fermeture, rifling, projectiles, powder, etc., of their systems of artillery. They are further supplemented by comprehensive tables giving this and other data in tabulated form, thus enabling one to obtain it more easily.

The author has added, in this edition, the distances of French military ports from the principal foreign ports, and the principal formulae of geometry and trigonometry.

The work is completed by a condensed but thorough and well written treatise on international maritime law, a very complete notice on torpedoes, together with a list of submarine cables of the world, tables for the conversion of English and French measures, tables for the evaluation of distances at sea, and a list of the personnel of the French navy and of the French naval commanders.

Altogether this publication seems to be as complete as possible and must prove of the greatest use to both naval and military officers.

A.H.Jr.

Mémoire sur un Nouveau Système de Bouches à Feu Démontables, Suite. Pierre S. Lycoudis, Lieutenant-Colonel du Génie, Armée Hellénique. Athènes: Charles Beck, Librairie Internationale. 1896, Pp. 36, with 6 plates of diagrams.

This pamphlet is a supplement to the author's original *mémoire* published in 1891, and contains new descriptions of proposed guns capable of being taken apart.

There are six new models described: the first a 75 mm. gun, weighing 309 kg., in three parts; the second, a similar gun, weighing 295 kg.; the third, fourth and fifth, field guns in two parts, weighing about 206 kg., which are intended to be used under circumstances where mobility may be increased at the expense of power, as in mountain warfare, for example.—they are derived from the second by omitting either the chase jacket or the breech jacket of the latter; the sixth is a modification of the first in two parts. The carriages proposed are each composed of three parts.

This system has its special application in mountain and siege artillery, permitting in the former the use of the largest calibers of field guns as well as howitzers and mortars for covered or plunging fire, and in the latter the use of the heavy guns and mortars now indispensable against armor protection.

The pieces now in use for mountain warfare have an initial velocity of 200 to 330 m., while those here proposed have velocities of 400 m. to 477 m.

The technical value of these guns, as well as the question whether the increased ballistic effect is not counterbalanced by their increased weight of material and length of column must be decided by experience.

J.P.W.

Quelques Mots sur la Défense et l'Attaque de Constantinople du côte de la terre. Par M.M. Constantinople: Otto Keil. 1896.

This study of the question of the land defenses of Constantinople considers the subject from the tactical and strategical point of view. It is composed of two parts, the first treating of the situation of the belligerents in 1877-78, the second picturing that produced by a new aggressor.

A careful discussion of the three lines which could be used to defend Constantinople shows that the first, that of Tchataldja—Derkos, although extending from sea to sea, is too long, 35 km., and would require 200,000 men to defend it; the second, by Pt. Tchékmédje—Asatli—Bogaskeui, although having only 14 km. of front, and requiring only 40,000 to hold it, while strong on the left, is easily turned by the valley of the Alibeysou on the right; and the third, passing from Makrikeui over Kavaskeui and Alibeykeui to Maslak, while subject to attack from the direction of Petit-Tchékmédje and San Stephano cannot be turned. The principal attack will evidently be on the west front, therefore a division will be sufficient east of the Alibeysou: 4 or 5 battalions well intrenched at Maslak (on the right), with batteries of long range guns, will be able to hold thrice their number in check, while the main force of the division occupies the heights above Pirgos, with a reserve of 4 battalions at Kiadhané, to reinforce either Maslak or the main body, or take part in a battle west of the Alibeysou.

After giving his conclusion on this point, the author discusses the case of an enemy using the Black Sea to effect a landing on the European shore of the Bosphorus, and comes to practically the same conclusions as to the fortifications required, viz: one south of Pirgos, another south of Bogaskeui and a third at Maslak.

The essay is well worth careful study, not only because of its tactical value, but also in view of the fact that Turkey promises to be the seat of war in the near future. J.P.W.

Strategisch-taktische Aufgaben, nebst Lösungen, von H. v. Gizycki. Heft 12. Fortgesetzt von Taubert, Oberst und Kommandeur des Eisenbahn-Regiments Nr. 3. (Der Kleine Krieg). Leipzig: Zuckschwerdt & Co. 1897. 2.50 Marks.

This latest number of this excellent series of problems in tactics treats of *minor operations* in the front of the army, such as raids against roads, railroads, bridges, lines of communication, depôts of supply, etc., conducted by the national guard or home defense troops, which do not form part of the regularly organized army.

Such operations have been carried on in past wars often enough in *rear* of the army, but the author thinks that in future wars they will take place in *front* of the army as well, but in a more military manner.

The army of the north occupies the line Falkenberg—Cottbus, north of the frontier of Saxony, that of the south the line Bautzen—Dresden, in Saxony. The first problem discusses the destruction of the bridges at Riesa and Langenburg by a national guard company of Liebenwerda; the second, the defense by a national guard company of a section of country between Ruhland and Elsterwerda against an attack by the army of the south, flooding it by opening the dams of the Elster; the third, the defense of the bridges at Torgau by a national guard company there against an attack from the south, by means of obstructions on the roads, abattis, entanglements, rifle pits, etc.: the fourth, an attack by this same company on the supply depôt at Dahme and the fifth an attack on that at Niemegk.

The conditions assumed are exactly those now existing in these places, and the character of the troops is exactly that of the organizations of civilians now existing. Altogether, the problems are reasonable and quite probable. At all events their study gives a very clear idea of the value of such auxiliary troops and the importance of their work and its effect on the general course of the campaign.

Incidentally, the measures taken for posting outposts under difficulties and many other points in "Security and Information" are brought out, and add an interest to the discussion. Like the rest of the series, this number is worthy of careful study.

The maps are rather indistinct, and contain too many details, but if supplemented by an ordinary atlas will be found adequate. J.P.W.

The Steam Navy of the United States. A history of the growth of the steam vessel of war in the U.S. Navy, and of the naval Engineer Corps. By Frank M. Bennett, Past Assistant Engineer, United States Navy. Warren & Co., 416 Wood Street, Pittsburgh, Penna. Pp. xv, 953, with index and numerous illustrations.

In view of the great interest taken in naval matters of late and of the importance and development of our modern navy, this book should prove not only interesting but instructive and of great service both to lay readers and to the class it represents—the Engineer Corps of the Navy.

The author begins with the first steam war vessel ever built, which happened to be in the American Navy, and traces from that clumsy beginning the slow development of the naval steamer, so that the book, as a whole, forms an orderly and progressive account of the growth of the war steamer and marine engine in the United States.

The introduction of steam into naval operations naturally revolutionized the fighting tactics of modern navies, and to fully as great an extent as gunpowder changed the methods of fighting on land. In precisely the same manner too, has the development of steam been hindered by a prejudice born of older things and intolerant of change.

"That steam will win an equal place and equal honor with gunpowder, and that the propelling and auxiliary engines of a ship of war will come to be recognized as arms fully as important in making up the ship's combative qualities as the turret and machine guns is a matter of simple logic; it only remains to be seen how long it will be before preconceived notions will admit the value of a new weapon." Hence, as a most essential part, the history of the Engineer Corps whose members have kept the standard of our steamers fully up to that of other nations and have made our new navy an established fact, is woven into the narrative.

A great deal is written about the deeds of those who fight in ships, but in the majority of cases very little is said of the *ships* themselves, or of their makers, or of that class of officials who not only design and build the vitals of all modern war-ships, but also fight in the ships as a part of their naval duties. The author supplies a lack that may be noticed in this respect in older histories of the navy, by giving, descriptively as well as statistically, something of the lives and deeds of those who have been intimately connected with the steam navy of the United States.

The book shows the author to be a man of literary ability, a painstaking and accurate writer. As a result of much research and arduous labor among the archives of the Navy Deparment, he presents us with information that forms an important and valuable history; and, in spite of much that is statistical—necessary it is true in a work of this nature—the reader's attention is held throughout the many pages. In addition to matter from official sources, he has also obtained much from correspondence and persons interested in or connected with the early navy, enabling him to collect in this volume a fund of information regarding the birth and development of the American steam navy that cannot be obtained elsewhere.

The book is adorned by more than one hundred and thirty illustrations consisting of fac-similes of drawings of machinery, boilers, methods of propulsion, with excellent illustrations of many of the early vessels, the *Fulton*, *San Jacinto*, *Mississippi*, *Niagara*, and those of later build such as the *New Ironsides*, *Dunderberg*, etc., down to and including many of the new battleships and cruisers.

A.H.Jr.

BOOK NOTICES.

[These books will be fully *reviewed* as space becomes available.]

Grundzüge eines Neuen Materiales für die Schweizerische Artillerie. Studie des Artillerie-Bureau. Bern, Switzerland. 1896.

This excellent treatise is a masterpiece of discussion in regard to the elements desired in the gun of the present. Our Professional Notes contain an analysis of its contents.

Memoirs of Marshal Oudinot, Duc de Reggio, compiled from the hitherto unpublished souvenirs of the Duchesse de Reggio. New York: D. Appleton & Co., 1897. One volume $2.00.

The French War and the Revolution. William Milligan Sloane, Professor in Princeton University. New York: Charles Scribner's Sons. 1893. One volume (The American History Series), $1.25.

Cavalry Studies from Two Great Wars. International Series, No. 2. Edited by Captain Arthur L. Wagner, 6th Infantry. Kansas City, Mo.: Hudson-Kimberly Publishing Co. 1896. $1.50.

Military Topography and Sketching. 1st Lieutenant Edwin A. Root, 19th Infantry. Revised and enlarged by the Department of Engineering, Fort Leavenworth, Kansas. Kansas City, Mo.: Hudson-Kimberly Publishing Co. 1896. $2.50.

Strategisch-taktische Aufgaben, nebst Lösungen. Von H. v. Gizycki. Heft 1. Fünfte Auflage. 1897. Leipzig: Zuckschwerdt & Co. 2.50 Marks.

Strategisch-taktische Aufgaben, nebst Lösungen. Von. H. v. Gizycki. Heft 7. Zweite Auflage. 1897. Leipzig: Zuckschwerdt & Co. 2.50 Marks.

Aperçu Critique des Passages du Danube pendant les Guerres Turco-Russes depuis 1828. Par un Officier Supérieur Turc. 1896. Constantinople: Otto Keil.

Tactical Studies on the Battles around Plevna. By Thilo von Trotha. International Series, No. 3. Edited by Captain Arthur L. Wagner, 6th Infantry. Kansas City, Mo.: Hudson-Kimberly Publishing Co. 1896. $1.50.

What is the most Practical Plan of Sanitary Organization for Active Service in the United States Army? By John Van Rensselaer Hoff, A. M., M. D., Major and Surgeon, U. S. A.

Fünf Taktische Aufgaben über Führung und verwendung der Feld-Artillerie. Gustav Smekal, K. und K. Hauptmann des Generalstabs-corps. 1. Heft. Wien: L. W. Seidel & Sohn. 1897. 3.60 Marks.

The Hotchkiss Automatic Machine Gun (rifle calibre). London: Harrison & Sons. 1896.

Die Awvendung der Photographie zu militärischen Zwecken. Bearbeitet von Kiesling, Premier-Lieutenant a. D. Halle a. S.: Wilhelm Knapp. 1896. Pp. 96.

Annual Report of the Board of Regents of the Smithsonian Institution, showing the operations, expenditures, and condition of the Institution to July, 1894. Pp. xl, 770, with index. Washington: Government Printing Office, 1896.

Besides containing the full report of the Secretary of the Institution, this volume is enriched by a General Appendix in which are contained about thirty-seven memoirs illustrating the more remarkable and important developments in physical and biological discovery: Schiaparelli's latest views regarding Mars; Light and Electricity; the Influence of Certain Agents in destroying the Vitality of the Typhoid and of the Colon Bacillus; Scientific Problems of the Future; etc.

Mittheilungen aus dem Gebiete des Seewesens, Volume xxv, Nos. iii and iv, Pola, 1897. Pp. 206. A handsome special edition containing The Austrian War in the Adriatic in 1866, an historical naval war study, by Ferdinand Ritter von Attlmayr. Published by the *Mittheilungen aus dem Gebiete des Seewesens* by order of the Imperial War Ministry (Naval Section).—With 4 portraits, heliogravures, 14 photogravures, 5 sketch-maps and 11 diagrams.

Frontières et Places Fortes des Principales Puissances par L. Amphoux. Paris. L. Baudoin, 30, Rue et Passage Dauphine. 1896. Pp. 76.

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Abbreviations employed in index are added here in brackets.

All the periodicals are preserved in the Artillery School Library, Fort Monroe, Virginia.

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Aldershot. Copies 6*d each.*

Arms and Explosives. [*Arms and Ex.*] *Monthly.*
Effingham House, Arundel Street, Strand, London, W. C. Per year 7*s.*

Army and Navy Gazette. [*A. and N. Gaz.*] *Weekly.*
3 *York Street, Covent Garden, London. Per year £*1 12*s* 6*d.*

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Box 2179 *Montreal, Canada. Per year* $2.00.

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22 *Paternoster Row, London. Per year* $6.00.

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33 *Norfolk Street, Strand, London. Per year £*2 6*d.*

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17 *Great George Street, London, S. W. Per year* 2*s.*

Journal of the United Service Institution of India. [*Jour. U. S. I. India*] *Monthly.*
Simla, India. Per year $2.50.

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12 *Hanover Square, London.*

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25 *Great George Street, Westminister, London.*

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Woolwich, England.

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58 *Richmond Street, Toronto, Canada.*

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5 *Adelphi Terrace, London, W.C.*

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13 *Quai Voltaire, Paris. Per year* 18 *Fr.*

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8 *Rue St. Dominique, Paris. Per year* 45 *Fr.*

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Schadenplatz 14, *Düsseldorf.* *Per year* $5.00.

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[*Mitth. Art. u. G.*] *Monthly.*
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Organ der Militaer Wissenchaftlichen Vereine. [*Vereine.*]
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5 *Calle de Cervantes, Barcelona, Spain. Per year* 32 *Fr.*

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Artillerie-Tidskrift. [*Art. Tids.*] *Bi-monthly.*
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59 *Ninth Street, Pittsburgh, Pa. Per year* $4.00.

Annual of the Office of Naval Intelligence. [*Naval Intelligence.*]
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Army and Navy Journal. [*A. and N. J.*] *Weekly.*
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Washington, D. C. Per year $3.00.

Bulletin of the American Mathematical Society. [*Bulletin Math. Soc.*]
University Heights, New York City.

Cassier's Magazine. [*Cas. Mag.*] *Monthly.*
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Digest of Physical Tests. [*Digest.*] *Quarterly.*
1424 *N. 9th Street, Philadelphia. Per year* $1.00.

Electrical Engineer. [*Elec. Eng.*] *Weekly.*
203 *Broadway, New York City. Per year* $3.00.

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13 *Park Row, New York City. Per Year* $3.00.

The Engineer. [*Eng. N. Y.*] *Fortnightly.*
106-108 *Fulton Street, New York City. Per year* $2.50.

Engineering News and American Railroad Journal.
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Engineering and Mining Journal. [*Eng. and Min. Jour.*] *Weekly.*
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The Iron Age. [*Iron Age.*] *Weekly.*
96-102 *Reade Street, New York City. Per year* $4.50.

Journal of Electricity. [*Jour. Elec.*] *Monthly.*
421 *Market Street, San Francisco, Cal.*

Journal of the American Chemical Society. [*J. Chem. S.*] *Monthly.*
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1737 *Monadnock Block, Chicago, Illinois. Per year* $2.00.

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13 *Locust Street, Philadelphia. Per year* $3.00.

The Photographic Times. [*Phot. Times.*] *Weekly.*
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Captain James M. Ingalls, 1st U. S. Artillery,
Lieutenant Erasmus M. Weaver, 2nd U. S. Artillery,
Lieutenant George O. Squier, 3rd U. S. Artillery,
Lieutenant Edgar Russel, 5th U. S. Artillery.

EDITOR.

Lieutenant John P. Wisser, 1st U. S. Artillery.

ASSISTANT EDITOR.

Lieutenant Andrew Hero, Jr., 4th U. S. Artillery.

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SEA-COAST MORTAR FIRE.*

Report of a Board, consisting of:
Captain James M. Ingalls, 1st Artillery, Instructor in Ballistics,
Captain John P. Story, 4th Arlillery, Instructor in Artillery,
1st Lieutenant John W. Ruckman, 1st Artillery, Acting Ordnance Officer.
convened by the Commanding Officer, U. S. Artillery School, to consider and report upon a paper by 1st Lieutenant John T. Honeycutt, 1st Artillery.

Parallel and Independent Fire, with special reference to Mortar Batteries,
by Lieutenant John T. Honeycutt, First Artillery.

The demonstration given below was prepared more than four years ago, being intended to supplement a different one of the same general principle, which latter demonstration, though never disproved, has been officially discredited by high authority.

The demonstration here given I sent at the time to Professor Merriman of Lehigh University, author of a standard work on probabilities, and one of the foremost mathematicians of the country, requesting him to make a carful examination of it, and inform me of his opinion as to its soundness. This he did and pronounced it to be correct.

The adverse opinion which I then held, and expressed, in reference to the proposed method of firing, and to the form of mortar battery which seemed to have been founded on this method of firing as its corner-stone, I have never seen any sufficient reason for changing; although I fully recognize that the defects of the system were greatly exaggerated in the paper referred to.

ile I can conceive of a battery being constructed with a

ERRATUM.

Page 334, line 29, omit "(*Lieutenant Honeycutt's*)". The paper ferred to is the one entitled: *The Grouping of Mortars in a ttery*.

mathematically, that in the long run we will hit a greater number of times by aiming the mortars independently.

The "probable number of hits" and "the probability of at least one hit" are two distinct mathematical questions, and it is only the first of these two questions that my demonstration, the one referred to above and the one given below, deal with. But at the same time it should be remembered that it is also the question only of the "probable number of hits" that was dealt with by General Abbot in his mathematical discussion of the subject, published in a report of the Board of Engineers recommending the adoption of the mortar batteries. And I presume it was at least partly on the strength of that mathematical discussion that the special form of battery was adopted.

That discussion showed the probable number of hits out of a large number of volleys fired under certain conditions, by the parallel method, from one of the then proposed mortar batteries. My demonstration shows that whatever that probable number may have been, it would have been greater had the mortars been supposed to be aimed independently at the target, but with all the other conditions the same in the two cases.

Therefore I claim to have shown that on the score of increased efficiency of fire no sufficient reason has ever been established for the adoption of the special form of mortar battery. And it does not require a mathematical investigation to show the increased danger to the men serving the battery over what that danger would be under some different arrangement.

DEMONSTRATION.

By the term parallel fire I believe is generally understood that method which has been proposed of aiming and firing the mortars of a battery with their lines of fire all parallel, or in other words where the pieces are to be fired with identical azimuths, elevations, and charges. To distinguish from this method the method in which each piece is aimed at the target independently of the others, I will call the latter the independent method.

My object is to show that when the guns or mortars of a battery are aimed by the independent method the probable number of hits will be greater than would be the case were they aimed by the parallel method.

Let us take the case of a volley fired from one of the adopted mortar batteries of 16 mortars, and show by which method of aiming we would have the greater number of hits. In the parallel method the mortars would all be aimed parallel to an imaginary mortar located at the center of the battery, which imaginary mortar, is supposed to be aimed at the target, making all allowances for wind, drift, time of flight, and speed of target in case it is a moving target. By the other method the mortars would be aimed independently at the target, each one just as the imaginary central mortar is supposed to be aimed in the parallel method.

Let us call the mortars by the numbers 1, 2, 3, etc., to 16. Denote by P^1 the probability of hitting the target with one shot from mortar 1, when the mortars are aimed by the parallel method and by P^2, P^3, P^4, . . . P^{16}, the like probabilities for the remaining 15 mortars. Denote by Q^1, Q^2, Q^3, R^4, . . . Q^{16}, the probabilities for the corresponding mortars when aimed independently. Now let us compare P^1 with Q^1. Q^1 is the probability that the shot would strike the target were mortar 1 aimed directly at the target, making allowances for wind, drift, etc. P^1 is the probability that mortar 1 would strike the target were it aimed not at the target but at a point 70 feet to the right or left and 132½ feet beyond or short of the target, those being approximately the distances of mortar 1 from the imaginary central mortar, parallel to which it is aimed.

There can be no question but that the shot from mortar 1 would be more likely to strike the target in the former case, that is when the mortar is aimed directly at the target and not at a point 70 feet to the right or left and 132½ feet in front or rear of the target. Hence we have $Q^1 > P^1$. The same method of reasoning will show that $Q^2 > P^2$, $Q^3 > P^3$, $Q^4 > P^4$, . . . $Q^{16} > P^{16}$. Adding these inequalities we have $Q^1 + Q^2 + Q^3 \dots + Q^{16} > P^1 + P^2 + P^3 \dots + P^{16}$. But Q^1, Q^2, Q^3, etc., being the probabilities in the case of the separate shots of the volley by the independent method, their sum $Q^1 + Q^2 + Q^3 \dots + Q^{16}$ is the probable number of hits by all the shots of the independent volley. In like manner $P^1 + P^2 + P^3 \dots P^{16}$ is the probable number of hits for the parallel volley.

Hence in the case of this battery the probable number of hits would be greater were the mortars aimed by the independent method than would be the case were the mortars aimed by the parallel method.

A similar course of reasoning would apply to any form of battery and to any number of volleys or shots and would give a similar result. Hence we have:

The probable number of hits from a battery of mortars will be greater if the mortars are aimed independently at the target than would be the case were the mortars aimed by the parallel method.

Report of Board.

The Board carefully considered the nature and scope of Lieutenant Honeycutt's paper and decided that the subject demanded a complete and thorough investigation, and proceeded to secure the requisite data and information for this purpose ; it then prepared its conclusions upon the paper considered in connection with certain official documents referred to the Board and data collected by it.

The documents above mentioned were not to be filed with this report, but were to be considered by the Board and returned to the Post Adjutant ; they are as follows:

1. Paper discussing the general question of mortar fire, especially with respect to the relative fronts of different mortar batteries proposed, when firing in directions making angles of considerable value with the principal axis of the battery. (Accompanied by a letter from Major Knight, Corps of Engineers).
2. General information accompanying the revised plans for the Typical Mortar Battery submitted by the Board of Engineers, August 5th, 1895.
3. Copy of letter of Col. G. H. Mendell, Corps of Engineers, dated September 30th, 1895, relative to the mortar battery at Fort Point, San Francisco Harbor, with description of same by Lieutenant Jos. E. Kuhn, Corps of Engineers, including a plat.
4. Copy of report, project, and estimate of Colonel C. R. Suter, Corps of Engineers, dated May 11th, 1896, for the ammunition service in mortar battery at Fort Point, California.
5. Memorandum giving tables showing the latest adopted dimensions of the zinc powder cases and wooden projectile cases for service, with other information.
6. *Grouping of mortars in a battery*, with the views of the Board of Engineers and certain officers of the Corps of Engineers thereon. (Accompanied by two letters from General Craighill, Chief of Engineers).

Owing to the great prominence given to the subject of mortar fire in our coast defense, and the wide scope of discussion contained in the above mentioned papers, the Board feels justified in treating the subject in a broader sense than it was presented by Lieutenant Honeycutt.

The Endicott Board recommended 581 high power guns of heavy calibers and 724 heavy rifled mortars for coast defense. In a total of 1,305 heavy guns 55.5% are mortars. With such great prominence given to mortars it is a matter of vital importance that they should be so arranged and served, as to deliver their fire with maximum efficacy. Therefore the arrangement and service to secure this result brings us to the question now under consideration.

The deck of a ship is its most vulnerable part for attack, provided it can be reached by shells having a vertical velocity-component sufficiently great to penetrate the deck and reach vital parts before exploding. It is the object of mortars to accomplish this purpose. From the nature of mortar fire, the projectile's penetrating power upon the deck increases with the range, being the opposite to that of direct fire against the ship's side. For example, at a range of five miles the 12-inch mortar projectile weighing 800 pounds fired at an angle of 60° would, on striking the deck, penetrate 6".3 of steel and have a vertical energy of about 3,500 foot-tons. This would penetrate the deck of any ship yet constructed. At 45° elevation this projectile would penetrate 4".3. At three miles these numbers are respectively 4".4, and 3".0. From this it appears that an enemy approaching a mortar battery should be attacked at extreme range, and as many shots as possible directed upon the ship before reaching the three mile limit. It is an accepted fact that mortar fire is not as accurate and cannot be made as accurate as direct fire. In the first place variations in muzzle velocity which can not be eliminated, have a greater effect upon high angle than upon direct fire, so far as accuracy is concerned, and in the second place the deviations of mortar projectiles from the plane of fire, for the same range, are not only greater than those of high power guns, but (what is more important to this discussion) are more irregular and far less easily calculable. For example, in the volley fired at 6,000 yards from the 12-inch mortar battery at Sandy Hook, April 11, 1895, at 60° elevation, the deviations from the plane of fire varied from 405 to 506 yards, and this too when all the mortars had been most carefully loaded by experts and all were fired within a few seconds of each other so that the effect of atmospheric variations was eliminated. It would have been impossible to predict that the shot from mortar No. 14 would go 506 yards or that from No. 30 go 405 yards to the right of the plane of fire. Even in the volley at 3,000 yards deviations to the right varied from 239 to 282 yards. (See General Abbot's article on Vertical Fire, *Journal of the U. S. Artillery*, volume v, whole number 20).

These great lateral deviations are compounded of drift, wind, and other effects, and (whatever may be accomplished in the future) at present they can not be predicted with accuracy.

Again, if the range be considered, we meet with correspondingly large variations and irregularities. Here again we find wind, atmospheric changes, and other causes nullifying our calculations. The upper air currents being unknown in strength and direction, may, on different days, cause great variations in range. The records of mortar fire at Fort Monroe for 1896 show a longitudinal error of 390 yards at 7,800 yards due to an unusually hot day, as appeared by computations afterwards made. This error corresponded to a change in elevation of about 4°.

Owing to these uncertainties in deviating causes it has become necessary, when firing on a given day, to determine the proper corrections in aiming by trial shots. Even when following this method the first shot may have an anomalous flight; therefore to obtain satisfactory data second or even third trial shots may be necessary.

It will therefore be in place here to devote some space to the subject of trial shots, which, when finally satisfactory, will serve to determine the center of impact of the volley, or as a guide in other firing. The error in locating the center of impact together with those made in locating the position of the target, and others, which will be noticed later, greatly complicate a purely mathematical discussion of the subject. The usual method of treating the subject is to determine from the position of the shots as plotted, their mean longitudinal and lateral dispersion with respect to the center of impact. Then by simple and well known methods to construct rectangles containing any desirable percentage of the whole number of shots. For comparison it is customary to construct the 25% rectangles. In the general case such as that with which we are now dealing, these rectangles furnish us with no standards as to the number of hits that may be expected upon an object of known dimensions. After determining and comparing fifty such rectangles, General Abbot, in one of his papers writes as follows:

"The error of supposing that these probable rectangles afford the means of estimating the probable chance of hitting a target at which the piece may be pointed in artillery practice, is apparent. They take into account no mechanical errors of pointing whatever, no errors in the assumed range, and no atmospheric conditions different from those affecting the experiments from which they were derived. Their proper use is relative, not absolute; but together with zones of other percentages of probability, which may be derived from those for the 50% zones by the use of tables based on the general law of error, they are very helpful in discussing problems like the present." (*Journal of the U. S. Artillery*, volume ii, page 317).

Again, on page 323—same article—he writes: "The great practical difficulty in all firing is to make the center of impact coincide with the target." * * * This statement is based upon a firing experience of 40,000 rounds under the most varied circumstances. Data on this question from our own records will be introduced and discussed later.

The range-finder error is of equal, if not of more importance than the mortar error as will be shown from official report giving tabulated results of the Lewis depression range-finder (officially adopted).

From these well known sources of error it appears that the probability of hitting a ship with mortar fire is not a simple question of ascertaining the number of shots that will strike within the area of the deck, located symmetrically with respect to the center of impact. On the other hand this *probability* is a complex function of three unknown variables. These are:

1. The mean deviation of the shots from their center of impact.

2. The distance of the center of impact from the designated position of the target.

3. The distance from the designated to the true position of the target.

In his mathematical inequality $Q^1 + Q^2 > P^1 + P^2 +$ Lieutenant Honeycutt considers the first of these quantities and ignores the remaining which are, in fact, the more important. Did these two not enter the problem, to modify, and in the majority of cases to nullify all conclusions drawn from the above expression, there could be no question as to the correctness of his conclusions. But they can not be disregarded or ignored in a thorough discussion of the question.

To express mathematically the relation amongst these three classes of errors, and obtain a general value for the probability function would doubtless be impossible, or if not so, the value would be so complicated that no general discussion could be made, and no practical conclusions drawn therefrom. It is, nevertheless, possible to find the value of the function for particular cases and elicit therefrom information applicable to the present subject. Assume the following notation:

$P =$ the general probability of hitting a given ship.

$E_R =$ the probable error in range of the shots from their center of impact.

$I_R =$ the distance in range from the center of impact to the position of the target as located by the range-finder (designated position).

$R_E =$ the distance in range from the designated to the true position of the target.

$E_d =$ the lateral probable error of shots from center of impact.

$I_d =$ the lateral distance from the center of impact to the designated position of the target.

$D_d =$ the lateral distance from the designated to the true position of the target.

$P_R =$ the probability of shots falling within a range zone equal to that occupied by the deck of a ship.

$P_d =$ the probability of shots falling within a lateral zone equal to that occupied by the deck of a ship. Then,

$$P = P_R \times P_d\,;\ P_d = f\,(E_d, I_d, D_d)\,;\ \text{and}\ P_R = f\ E_R, I_R, R_E).$$

I. VARIATIONS IN THE POSITIONS OF SHOTS IN A GROUP FIRED UNDER FIXED CONDITIONS.

1. *In lateral direction.*

Commencing with the lateral probability function we shall consider the errors which enter it, the causes which alter them, and the conditions which fix their values. E_d is found by multiplying the mean of the lateral errors from the center of impact by 0.8453. It is owing to irregularities in the lateral deviation from the plane of fire that these errors exist. But for these irregularities in lateral deviations and similar irregularities in range, all shots would strike in the same hole, and an object at this spot would receive all shots, but in any other position could not possibly be hit. This, however, is the limiting case, and is impossible in practice.

2. *In range.*

E_R depends upon the variations in range; its value is found by multiplying the mean of the sum of the differences between the mean and individual ranges by 0.8453.

These two classes of errors may be considered as made up of all the irregularities in their respective directions for which we cannot account, or which creep into our work after all possible corrections have been made. Variations in initial velocity, unsteadiness of flight, unknown variations in atmospheric conditions, changes in wind components, errors in laying, and doubtless many other variable agencies, combined to produce them.

Although the individual errors in both range and lateral direction are apparently anomalous in their relations to one another, each class of errors is known to follow the laws of probability and may be analyzed by them. In mortar fire E_d and E_R hold certain relations to each other. General Abbott in discussing the question found in fifty groups whose ranges varied from one mile to six, that $E_d = 0.0018\ R$ and $E_R = 0.0058\ R$. Dividing the second equation by the first, member by member, gives $\frac{E_R}{E_d} = \frac{58}{18}$ (R for the same group being the same in each equation), or $E_R = 3.22\ E_d$.

From the 8 groups fired at Sandy Hook, with No. 1 steel mortar, at ranges from about 9,000 to 12,000 yards, on April 16, May 2, and May 23, 1895, we have $E_R = 2.81\ E_d$. (For this datum see table on following page).

The firings at Fort Monroe, Va., on June 27th, August 10th and 13th, 1896, furnish three groups of 8, 8, and 11 shots, from which we obtain $E_R = 3.43\ E_d$. Taking an average of the whole 61 groups we find $E_R = 3.17\ E_d$, which differs but little from General Abbott's value, and not materially from the value obtained from firing at Fort Monroe, Va., in actual practice at a target (1st shot in each group omitted). The fact that the mean errors in range are always much greater than the lateral is well recognized in all branches of gunnery. This principle is extremely important in mortar fire, and in this discussion finds extensive application.

DEVIATION OF CENTER OF IMPACT FROM DESIGNATED POSITION OF TARGET.

In taking up the deviations of the center of impact from the object aimed at, that is, the position of the target as located by the range-and-position-finder, we have not only a more difficult problem, but one in regard to which little is definitely known and upon which accurate data are scarce. The correctness of General Abbott's statement above quoted, concerning the difficulty of making center of impact and target coincide falls within the experience of all familiar with practical artillery.

As a matter of fact the center of impact rarely or never coincides with the target, and in this discussion it becomes a matter of great importance to know what causes affect this deviation and to obtain some idea of its probable value.

I. LATERAL DEVIATION OF CENTER OF IMPACT.

The lateral deviation for mortar fire is enormous. (See table of results of firing at Sandy Hook.) and unless a suitable correction can be foretold and applied it becomes necessary on firing, *Table Showing Relation Between Range and Dispersion of Shots fired at Sandy Hook and Ft. Monroe.*

Date.	Elevation.	Mean range.	Mean deviation from plane of fire.	Mean deviation from center of impact.		Fifty per cent zones.		Maximum Dispersion.		Rectangle containing all shots.	Mean angular deviation.
				Longitudinal.	Lateral.	Longitudinal.	Lateral.	Longitudinal.	Lateral.		
1895.											
April 16	45°	10791.2	723.8	55.76	27.84	47.13	23.53	137	105	137 × 105	3° 50′ 45″
"	50°	10717.6	719.6	24.08	23.12	20.32	19.58	87	67	87 × 67	3° 51′
"	55°	10214.2	853.2	37.00	3.00	31.27	2.54	128	17	128 × 17	4° 47′ 30″
May 2	60°	9285.0	873.6	36.00	14.32	30.43	12.10	135	43	135 × 43	5° 24′
May 23	60°	9860.6	839.4	36.84	9.92	48.16	8.39	226	40	226 × 40	4° 53′
"	55°	11039.2	799.4	45.36	7.92	38.34	6.70	132	21	132 × 21	4° 09′ 10″
"	50°	11641.4	671.2	43.12	11.84	36.45	10.00	125	37	125 × 37	3° 18′ 15″
"	45°	11859.0	541.8	8.8	11.44	7.44	9.67	35	45	35 × 45	2° 37′ 05″
1896.											
June 27	56° 32′	5975.0		30.25	7.53	25.56	6.36	104	38	104 × 38	4° 05′
August 10	57° 15′	6921.0		54.25	19.00	45.86	16.06	240	76	240 × 76	3° 10′
August 13	54° 25′	7764.2		50.35	12.75	42.56	10.77	214	82	214 × 82	3° 34′

to determine it by experiment. This will probably have to be done in any case, but the more errors that can be predicted the more can be eliminated on the first shot.

Lateral deviation varies for each range, and for each elevation which will give the same range; it changes with each set of conditions; and, other things being equal, appears to increase rapidly with the elevation. The principal elements which compose this deviation are drift, rotation of earth, and wind effect.

As an example we present the computed elements of a 12-inch mortar trajectory. Elevation 50°, weight of projectile 800 pounds, initial velocity 1,200 feet. The numerical values are given in the following table and are represented graphically in Plate I.

Inclination.	Altitude. Feet.	Horizontal distance.		Time of flight.	Remaining velocity.
		Feet.	Yards.		
50°	0	0	0	0	1200 f.s.
45	3605	3280	1093	4″.43	1013
40	5863	5735	1845	7″.93	895
30	8475	9414	3137	13″.40	761
20	9767	12232	4077	17″.72	685
0	10605	16768	5589	24″.89	622
−20	9808	21013	7004	31″.82	641
−30	8698	23377	7792	35″.78	682
−40	6747	26137	8712	40″.52	750
−50	3253	29586	9862	46″.64	852
−55.43	0	32024	10675	51″.19	929

The theoretical drift for this range and elevation, computed by the most reliable method known, is 271 yards.

The effect of the earth's rotation is always to the right in the northern hemisphere, and by the most reliable formula (Poisson's Formula) at hand, is 64.75 yards when fired in the meridian, and 36 yards when fired perpendicularly thereto.

The average deviation of five shots at 50° elevation for an average range, 10715.6 yards, fired at Sandy Hook, was found to be 719.6 yards.

The cross wind component observed at the earth's surface was 3.9 miles per hour, blowing from left to right. The computed effect of this wind operating throughout the flight would be about 21 yards. Taking therefore the whole theoretical corrections predictable from the three causes above mentioned, we obtain 357 yards, or about half what was actually measured for a similar trajectory. This great discrepancy conclusively shows that we are still unable to obtain satisfactory results from present theories.

Winds, Their Velocities, Directions and Effects.

The great height of mortar trajectories (see table giving relation between maximum ordinate, elevation, and range), such as that shown in Plate I, renders it highly probable that, during flight, the projectile is acted upon by winds differing in strength and direction from those observed at the earth's surface. This view of the question led the Board to make inquiries as to the relation between the velocity and direction of winds at the sea

Table Giving Relation Between Elevation, Range and Maximum Ordinate.

φ Elevation.	X Range—yards.	Maximum ordinate of trajectory.		φ Elevation.	X Range—yards.	Maximum ordinate of trajectory.	
		Yards.	Feet.			Yards.	Feet.
		$Y_o =$	.15 X*			$Y_o =$	.32 X
30°	4000	600	1800	50°	4000	1280	3840
	5000	750	2250		5000	1600	4800
	6000	900	2700		6000	1920	5760
	7000	1050	3150		7000	2240	6720
	8000	1200	3600		8000	2560	7680
	9000	1350	4050		9000	2880	8640
	10000	1500	4500		10000	3200	9600
		$Y_o =$	.19 X			$Y_o =$	.38 X
35°	4000	760	2280	55°	4000	1520	4560
	5000	950	2850		5000	1900	5700
	6000	1140	3420		6000	2280	6840
	7000	1330	3990		7000	2660	7980
	8000	1520	4560		8000	3040	9120
	9000	1710	5130		9000	3420	10260
	10000	1900	5700		10000	3800	11400
		$Y_o =$	.23 X			$Y_o =$	.47 X
40°	4000	920	2760	60°	4000	1880	5640
	5000	1150	3450		5000	2350	7050
	6000	1380	4140		6000	2820	8460
	7000	1610	4830		7000	3290	9870
	8000	1840	5520		8000	3760	11280
	9000	2070	6210		9000	4230	12690
	10000	2300	6900		10000	4700	14100
		$Y_o =$	.27 X			$Y_o =$	.60 X
45°	4000	1080	3240	65°	4000	2400	7200
	5000	1350	4050		5000	3000	9000
	6000	1620	4860		6000	3600	10800
	7000	1890	5670		7000	4200	12600
	8000	2160	6480		8000	4800	14400
	9000	2430	7290		9000	5400	16200
	10000	2700	8100		10000	6000	18000

level and at other points of high altitude such as Mt. Washington. Data on this subject are scarce and what do exist are scattered and difficult of access.

Through the courtesy of the Chief of the Weather Bureau we obtained the accompanying tables:

These results are shown graphically in Plate II, and are summed up below. Plate II conveys to the eye a clear idea of the difference in winds between Portland, Maine, and Mt. Washington. The first important and rather remarkable fact shown by these figures is that the average hourly wind velocity observed at Mt. Washington for the period of 10 years from 1877 to 1886 was 4.43 times that at Portland, Maine.

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* See General Tables for Mortar Firing—Ingalls—*Journal U. S. Artillery*, No. 1, 1896, p. 58.

Passing to wind directions we have the following synopsis:

Number of times observed.

Mt. Washington.		Portland, Maine.
North	487	1461
N. E.	503	915
E.	277	553
S. E.	438	657
S.	492	1573
S. W.	891	1635
W.	1710	1708
N. W.	5906	1758
Calm.	159	596
Total . .	10863	10856

Number of times observed from West, or with components from that direction.

Mt. Washington.		Portland, Maine.
S. W.	891	1635
W.	1710	1708
N. W.	5906	1758
	8507	5091

From east, or component from that direction.

N. E.	530	915
E.	277	553
S. E.	438	657
	1245	2125

From north, or component from that direction.

N.	508	1556
N. E.	530	915
N. W.	5906	1758
	6944	4229

From south, or component from that direction.

S.	492	1573
S. W.	891	1635
S. E.	438	657
	1821	3865

These results show that at Mt. Washington the direction of the wind is often different from that at Portland. At the former point the wind was observed from the northwest alone 5906 times, or 54.1% of the whole time, and with a component from the west 8507 out of a total of 10,863, or 78.3% of the whole time. The percentages for these directions at Portland are respectively 16 and 48.

From this it appears that the wind on top of Mt. Washington is from the northwest more than half the time and from a western direction nearly four-fifths of the time.

When these facts are coupled with the higher average velocity found at Mt. Washington it is evident that surface winds are no index as to what takes place in the upper part of a high trajectory.

According to the investigations of Professor Loomis the neutral zone between these upper and lower winds is near the altitude of 6,000 feet. Under the assumption that the wind's velocity and direction may be different above and below this height, the effect upon a projectile was computed for seven different cases. The trajectory taken was that shown in Plate I, and the computed deviations are shown graphically in the seven curves A_1, A_1, A_2, A_2, etc. The results are based upon the assumption that throughout the flight a wind of 20 miles from left to right is in force below the height 5,863 feet. Above this the wind is supposed to be 0 for the A_4 A_4 curve, + 20 for A_5 A_5, + 40 for A_6 A_6, and + 60 for A_7 A_7; -20 for A_3 A_3 -40 for A_2 A_2 and -60 for A_1 A_1. The numerical values are also given in the accompanying table.

In column 0 and -20 in the table we have the relative values of the same wind above and below 5,863 feet, from which we see that in this particular case the wind below the 5,863 point is the more important. With 20 miles below and 60 above, acting in

Table Showing Effect of Lateral Wind under Varying Circumstances.

Lateral Deviation—Yards.

Wind 20 miles an hour, below 5,863 feet and blowing from left to right +.

Wind above 5,863 feet.	0	+20	+40	+60	—20	—40	—60
Points on trajectory.							
1	1.55	1.55	1.55	1.55	1.55	1.55	1.55
2	4.77	4.77	4.77	4.77	4.77	4.77	4.77
3	10.70	11.95	13.19	14.44	9.85	8.40	7.16
4	15.83	18.94	22.04	25.15	12.67	8.99	5.86
5	23.56	32.53	41.49	50.46	15.13	5.90	3.07
6	31.59	47.85	64.10	80.36	15.33	—1.47	—18.00
7	35.75	57.60	79.44	101.28	14.48	—7.64	—29.48
8	41.10	70.37	99.64	128.91	12.34	—17.60	—46.47
8½					11.22	—21.36	
9	48.88	89.08	129.28	169.47	8.64	—31.44	—71.63
10	56.39	105.03	153.59	202.08	8.37	—40.30	—88.80

the same direction, we have a deviation of 202.08 yards to the right, but with 20 miles acting to the right below and 60 to the left above we have 88.8 yards to the left, or a difference of 290.88 yards.

As the wind velocity is wholly unknown in this upper region there is a possible unknown deviating agent in our problem whose limits may even exceed these values. It is not likely, however, that the great discrepancy pointed out above can be wholly accounted for in this manner, but no doubt this is a cause of lateral variations from day to day, which at present can not be predicted or taken into account until trial shots have been fired, observed, and located with reasonable accuracy.

Careful and systematic tabulation of firing results over the field of fire with ranges for a fixed elevation, and different elevations for a fixed range, would in time determine within moderate limits, the average correction for the place and field of fire. With these known, the correction to be found by trial would be reduced to a minimum, and the accuracy obtained by a second trial and following shots would be increased.

Target practice with mortars in our service is as yet too limited, and has been conducted under circumstances too disadvantageous, to define clearly just what may be expected in future, but the results so far obtained from this season's work are promising. With more experience in determining the proper corrections to be made, the indications are that good line shooting will be obtained.

In evidence of this statement we offer here the firings at Sandy Hook in 1895, from the steel mortar No. 1, the details of which have already been mentioned. Omitting the first shot of each of the 8 groups, as trial shots and correcting in each group for the angular deviation of their respective trial shots in the second and following shots, the lateral deviations in yards of the center of impact of the groups of four would presumably have been as follows:

Lateral deviation of center of impact from plane of target.

1.	April 16, 1895	2.20	yards	R.
2.	April 16, 1895	6.15	"	R.
3.	April 16, 1895	2.10	"	R.
4.	May 2, 1895	6.10	"	L.

5.	May 23, 1895	5.28	"	R.
6.	May 23, 1895	1.40	"	L.
7.	May 23, 1895	6.45	"	L.
8.	May 23, 1895	4.55	"	L.

Here are four centers to the right and four to the left of the vertical plane of gun and target with a total of 15.75 yards in the one case against 18.50 yards in the other. These deviations are small and the average position of the 8 centers is less than half a yard to the left of the vertical plane through the gun and target.

Taking the three groups fired at Fort Monroe, Va., 1896, we have (omitting the first shots as trial shots):

Lateral deviation of center of impact from plane of target.

1.	June 27, 8 shots	2.37	yards	L.
2.	August 10, 8 shots	15.75	"	R.
3.	August 13, 11 shots	3.36	"	R.

Average lateral deviation of three centers of impact 5.5 yards to the right.

Taking the co-ordinates of these three centers along with seven others representing the mean position of 2nd and 3rd shots of groups fired at Fort Monroe we have the average lateral position of the 10 centers one yard to the left of the target. (See Plate III).

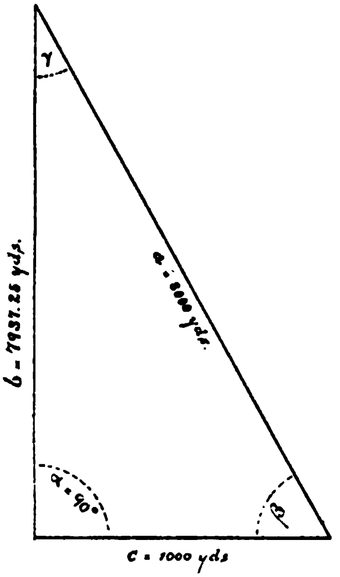
From this we conclude that with trial shots the lateral correction should be obtained, and the center of impact of a volley or number of independent shots placed near the vertical plane passing through gun and target.

2. DEVIATION IN RANGE OF CENTER OF IMPACT.

While much that has been said with respect to lateral deviations applies also to this class, the latter at this date is much more vague and unsatisfactory. Lateral deviations are in all cases easily measured from the plane of fire and accurate values readily obtained, moreover, abundant data for this class of deviations are at hand. To obtain errors in range, however, the firing must be designed to attain some *fixed* range; but unfortunately in our service there has been but little firing of this kind.

The general remarks and conclusions above in regard to wind apply here, and, for the present, wind effects can not be predicted. Changes in atmospheric conditions are important, but their effect upon the range can probably be calculated.

α	β	γ	a	b	c	± Δ α	± Δ β	± Δ a	± Δ b
90°	82° 50′ 10″	7° 10′ 50″	8000.00	7937.25	1000	0	0	0	0
90° 1′	" 51′ 10″	" 8′ "	8037.34	7974.60	"	± 1′	± 1′	± 37.34	± 37.35
90° 2′	" 52′ 10″	" 6′ "	8074.80	8012.06	"	± 2′	± 2′	± 74.80	± 74.81
90° 3′	" 53′ 10″	" 4′ "	8112.62	8049.88	"	± 3′	± 3′	± 112.62	± 112.63
90° 4′	" 54′ 10″	" 2′ "	8150.80	8088.05	"	± 4′	± 4′	± 150.80	± 150.80
90° 5′	" 55′ 10″	" 0′ "	8189.33	8126.59	"	± 5′	± 5′	± 189.33	± 189.34



To the accuracy of observed lateral deviations there is the check of direct view from the firing point which defines beyond doubt the sense of a deviation and in a measure its amount, but viewed from the same point, the best observers differ widely as to the nature and extent of errors in range. Again in observing from the end of a base, small angular errors made by the observers, change the target's position but little in the lateral direction as seen from the gun, but for mortar ranges such errors, as a rule, cause great errors in range. The above illustration will make this clear. Assume a triangle with base of 1000 yards, $a = 90°$ and $a = 8000$ yards. The other parts of the triangle will be those shown in the figure. The errors in range from either station for inaccuracies in measurement of angles will be as in table.

If conversion or relocation takes place at one of the stations the azimuth of the object would be in error but a few yards even when both angular errors are positive and equal to 5′. When there is a 5′ positive or negative error in but one angle the range will be changed by a little less than one-half the tabular values above, and the azimuth error will be made only when an angular error is made at the station at which re-location takes place. When both errors are equal but have opposite signs there will be no appreciable change in the range but the error in azimuth will be the same as in the case where both errors are positive or negative.

It is thus seen that small errors in the base angles will cause important range errors. These results will not be materially changed by the position of the gun if near either of the stations or anywhere near the base line or behind it. As a rule the range will be more sensitive to variations than the azimuth, and shots fired as trial shots, however observed and reported, are liable to have larger errors in range than in the lateral direction. As volley or other firing will be based upon the result of trial shots the centers of impact of the volleys will be subject to such errors also. From this it follows that the dispersion in range of centers of impact should be greater than that in the lateral direction. Practice confirms this conclusion.

We present in Plate III a group of 10 centers of impact the result of firing at Fort Monroe, Va., during the summer of 1896. The references to them already made, with the legendary notes sufficiently explain them.

The rectangle containing all these centers is 50 x 173 yards showing a *range deviation* 3.46 times the lateral deviation. From their average position it will be seen that they are distributed with practical symmetry around the target. Treating these points as so many errors from their mean position we find:

50% zone of dispersion in range, 32.98 yards.

50% zone of dispersion in lateral direction, 8.79 yards.

50% zone of dispersion in range, 3.75 × 50% zone of lateral dispersion.

These figures indicate a law of dispersion for centers of impact similar to that shown for the dispersion of the shots themselves.

If then these centers in the long run arrange themselves symmetrically about the target, the gains and losses due to these errors, short or beyond, to the right or left, would ultimately, in a large number of groups, balance one another; but for an independent group or volley the particular error of the group or volley in question must be applied.

This is shown by the plot of centers shown in Plate III. The average of positions is practically the target; and yet in considering the groups of June 27, August 10th or 13th, the errors made by the center of each particular group must be applied.

We now present additional information on the subject of trial shots where, in regard to the accuracy of the observations of the range and position of shots, the conditions were most favorable.

In Plate III are three groups of shots, the nature of which is explained in the legend.

The group Figure 1 is made up of 1st shots of groups fired at

Fort Monroe, Va., on different days; Figures 2, and 3, are made up of the 2nd and 3rd shots of these groups respectively. These figures indicate what may be expected from 1st, 2nd and 3rd trial shots in the present condition of mortar practice.

In the first all but one are over, one only being within 100 yards of the target. The *Royal Sovereign* with center at the target would not have been hit in any position. In the second all shots but two are within 100 yards of the target. The ship bow on would have been hit twice; broadside to, once; and diagonally across, lying in 1st and 3rd quadrants twice. In the third group, all shots but two are over, five are within 100 yards of the target, and the ship bow on would have been hit twice, and diagonally in 1st and 3rd quadrants once. The line shooting in the 2nd and 3rd figures is practically the same, but the range shooting in the 3rd is greatly improved over that in the 2nd. This is an additional proof that the correction for range is the more difficult.

Greater familiarity with mortar practice will doubtless increase the accuracy of first and following shots. The formulation of better methods, compilation of essential data not available in this firing, and the application of such corrections as experience shows to be constant under fixed known conditions, will operate to attain this end. This probable improvement may, however, be neutralized in action by more unreliable observation of trial shots, and of the firing generally.

Passing these considerations, the group of 1st shots indicates that for the present at least, more than one trial shot will be necessary in order by this means to direct with accuracy the center of impact of a volley or independent firing upon the target.

3. ERRORS OF THE RANGE-AND-POSITION-FINDER.

Reliable information upon this class of errors is scarce. The Lewis depression range-and-position-finder, being the only one adopted for our service, (officially), is the only one whose errors will find application in this discussion. The only experiments with this instrument in reference to its error in locating the target (known to the Board) are recorded in the Reports of the Board of Ordnance and Fortification for the years 1894 and 1895.

Lateral Errors.

An examination of these reports fails to disclose any relation between range and errors in azimuth. The errors in azimuth are as a rule small, being but a few minutes of arc. As the length of a minute of arc increases directly with the range the lateral deviation in yards will vary directly with it. This principle was accepted in the last three mean ranges of the range-finder used in the curves in Plates VI, VII, and VIII.

If the azimuth circle be carefully adjusted the azimuth error should be very small, since the measurement depends on the observer's ability to place a vertical wire on a definite point of the object, and to read a vernier correctly.* In the reports above referred to constant errors seem to exist. Had these apparent constant lateral errors been eliminated from the result obtained for ranges 7,828, 9,075 and 10,401 yds., the remainder would have been 6'.56 — 5'.85 = 0'.71. equal to about 2 yards at the extreme range, a quantity practically negligible.

The lateral errors for five ranges from about 6,000 to 10,500 yards were determined and will be found in the following table.

Errors in Range.

From the nature of the case the causes of error in this direction are more difficult to detect and eliminate than in the other. From the tables giving results of tests of range-finders, ranges were chosen not differing more than 500 yards either way from the mean range whose error was desired.

The mean of the differences between the ranges given by the range-finder and the measured ranges multiplied by 0.8453 gives the probable error in range.

The following table contains the results for five mean ranges from about 6,000 to 10,500 yards. The mean ranges correspond to the ranges of shot groups as nearly as was obtainable from data at hand. The inaccuracy due to the small differences between these mean ranges and the corresponding mean range of groups of shots to which they are compared is not appreciable. The mean of the range-finder errors varies with the range from about 1.5% at 6,000 yards to about 2.3% at 10,500 yards. The irregularities in the means of the errors both laterally and in range are probably due to the limited number of observations; it is to be observed that the greater this number in the five cases considered the more regular the results appear.

As is shown in the following table, for shots and for centers of impact of groups, the range errors of the range-and-position-finder are the more important, and, in fact, are the principle ones to be considered.

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* 'Fiske and Lewis give azimuth about right, and both points plotted from their observations nearly coincide."

Note by 1st Lieutenant H. L. Harris, 1st Artillery, Executive Officer, Range Finder Board. See report of Board of Ordnance and Fortification, 1895, pp. 38-39.

	In range.			Lateral.			50% zones.		
Mean range of group of shots.	No. of observations. R. F.	Mean measured range.	Mean of errors.	No. of observations.	Azimuth errors. Minutes.	Errors. Yards.	Range.	Lateral.	50% range zone / 50% lateral zone.
5975.0	12	6036.6	92.83	12.00	11.00	19.30	78.47	16.30	4.81
6921.0	9	7039.5	164.38	20.00	4.40	9.00	138.92	7.62	18.23
7764.2	11	7828.1	231.36	46.00	6.56	14.95	195.57	12.64	15.47
9285.0	7	9075.4	191.22	46.00	6.56	17.72	161.64	15.00	10.78
10754.4	7	10401.0	225.00	46.00	6.56	20.55	190.19	17.36	10.96

In all these cases the errors in range are greater than the respective errors in the lateral direction.

The lateral errors in these cases seem to be practically equal, but there is great disparity with respect to those in range. Notwithstanding this disparity in the probable range errors of (1) the shots referred to their center of impact, (2) the center of impact with respect to the designated position of the target, and (3) this latter point referred to the true position of the target, *the range errors in all three cases seem to result from similar causes and to follow similar laws.*

A comparison of the range-and-position-finder 50% zones with the 50% zone of corresponding shot groups gives the relations included in the following table:

Mean ranges.		50% range zones.		50% lateral zones.	
Shots.	Range finder.	Shots.	Range finder.	Shots.	Range finder.
5975.0	6036.6	25.56	78.47	6.36	16.30
6921.0	7039.5	45.86	138.92	16.06	7.62
7764.2	7828.1	42.56	195.57	10.77	12.64
9285.0	9075.4	30.43	161.64	12.41	15.00
10754.4	10401.0	42.23	190.19	21.54	17.36
Totals. . . .		186.64	764.79	67.14	68.92
Average. .		37.33	152.96	13.43	13.78

Mean of range-and-position-finder 50% range zones = 11.1 × mean of 50% range-and-position-finder lateral zones.

Mean of range-and-position-finder 50% range zones = 11.4 × mean of 50% lateral zones of shot groups.

Mean of range-and-position-finder 50% range zones = 4.10 × mean of 50% range zones of shot groups.

The means of the 50% lateral zones of range-and-position-finder and shot groups are practically equal while the means of the 50% range zones of the former is 4.10 times the 50% range zone of the latter.

The form of the 25% rectangle of the range-and-position-finder is long and narrow. The elongation of the 25% rectangles of the shot groups or the greater dispersion in range has a tendency to compensate for the great variation in range to which the target's position is subject; but from the fact that the mean length of the 25% rectangle for the range-and-position-finder is 4.10 times that for the shot groups, the natural dispersion of shots in range of an independent battery does not appear to be sufficient. This conclusion brings out the advisability if not the necessity for extending the dispersion of shots in range beyond that which naturally takes place, either by adopting a special form of battery and using parallel fire, or, in the general form of battery, by some system of laying by which the same result may be obtained.

With the elucidation of this question in view the following curves based upon results of mortar practice have been prepared; it being the opinion of the Board that practical examples will furnish the only reliable standard for this purpose. We therefore proceed to apply the principles just brought out to the five groups of shots already mentioned. In what follows we shall endeavor to develop the most advantageous form for the distribution of the shots in mortar fire.

PRACTICAL ILLUSTRATIONS.

As the following illustrations are based almost entirely upon the properties of the probability curve, a few words will be given as to the method of constructing it, and the nature of its properties.

The methods of constructing and combining the curves given in the different plates are identical for all, both for the longitudinal and lateral curves; a description of these methods for one set of curves therefore will be sufficient. The corresponding curves in plates IV to VIII inclusive, differ only in numerical values and results.

This curve is symmetrical with respect to the axis of probabilities and the axis of errors is an asymptote to both branches.

The Probability Curve.

The maximum ordinate corresponds to zero error and is therefore the intercept on the axis of probabilities. The equation for the curve is $y = \frac{h}{\sqrt{\pi}} e^{-h^2x^2}$, in which h, π and e are constants, π and e being known and h determined by the errors considered; x, denoting the errors, is the variable, and y the corresponding function. The equation is also written $y = \frac{2h}{\sqrt{\pi}} \int_0^x e^{-h^2x^2} dx$, which expresses the probability of an error within a zone included between $+ x$ and $- x$, or the probability that an error is numerically less than x. Any given area of the curve bounded by ordinates is to the whole area as the number of errors falling between the limiting ordinates is to the whole number of errors. From tables computed for the purpose the area between any two limiting ordinates is easily found in terms of the whole area. Bearing these principles in mind, the curves used in the following illustrations are easily interpreted and compared.

As the errors in our problem are symmetrically distributed around the center of impact, this point in all cases is the origin of co-ordinates to which all points, such as position of target, are referred. The two branches of the curves being identical, and positive and negative errors of the same value equally probable, it is only necessary to consider one-half of the curve, remembering, however, that but half the errors will be involved.

The problem now to be considered is to compare the areas of the independent battery curves with the typical battery curves for the same position of the ship, and ascertain from the comparison the relative values of the two methods of fire under average service conditions.

Comparison of Probabilities.

The number of shots in a volley from the typical battery being 16 and this number offering simplicity in construction of curves, it is taken in the discussion as a basis of computation and comparison. The positions of the mortars in the typical battery are shown in plan on each plate. The target and range in all cases are assumed the same for both batteries, the range being estimated from the center of the typical battery, and the same degree of accuracy is assumed in both cases. In other words the projectiles from the typical battery will strike in positions with respect to each other the same as those of the mortar from which they were fired. This assumption is not strictly true but deviations from these assumed positions will not affect the argument, since the projectiles from the same pieces fired at the same instant by any other method would suffer like irregularities and would deviate equally from their predicted positions. This principle, that nothing is gained or lost in the accuracy of the gun by either method is accepted by all who have discussed the question and is the basis of the argument in Lieutenant Honeycutt's paper. Accepting with him the assumption that the distribution of the projectiles in the typical battery will correspond to the plan of the battery, we are able to deduce the results below given.

The numerical values of the probabilities are in all cases multiplied by large numbers in order to obtain suitable vertical scales for the ordinates to the curves. These numerical co-efficients are not the same for longitudinal and lateral curves, nor are they the same for either of these sets of curves in all five plates; but for the same plate the co-efficient is the same for all the curves in either class. Probabilities from the different longitudinal curves on the same plate are therefore directly comparable, and and the same applies to the lateral curves and probabilities.

Longitudinal curves run lengthwise of the sheet; lateral curves run transversely across below the former.

The decimal numbers along the axis of errors refer only to the independent battery curves and indicate the fractional part of 8 shots that will probably be found between their respective ordinates and the origin. The decimal numbers near or on the range-finder curves in like manner indicate the fractional part of half the number of observed positions of the ship which will probably be found between their respective ordinates and the origin.

The lateral curves are similar in all respects to those just described and the decimal numbers along the axis and range-finder curves denote, as above, similar fractional parts with respect to lateral deviations.

First Group, Plate IV.

Fired at Fort Monroe, Va., June 27th, 1896, 9 shots. 8 shots used in obtaining the following data (1st shot omitted).

Mean range of shots	5975.00 yards
Mean of errors in range from center of impact	30.25 "
Mean of errors in lateral direction from center of impact	7.53 "

Probable error in range (E_R)	25.56 yards
Probable error in lateral direction (E_d) . . .	6.36 "
Deviation in range of center of impact from designated position of target (I_R) . .	−19.75 "
Deviation in lateral direction of center of impact from designated position of target (I_d)	+2.37 "

Range-Finder.

Mean range	6036.6 yards
Mean of errors in range	92.83 "
Mean of errors in azimuth 11′, equal to . .	19.30 "
Probable error in range	78.47 "
Probable error in azimuth	16.30 "

To construct the curve for the range errors of the above group of shots we have $y = \frac{h}{\sqrt{\pi}} e^{-h^2 x^2}$, in which the value of h must be substituted, viz. $h = \frac{\rho}{r}$; $r = 0.8453 \times 30.25 = 25.56 = E_R$; $\rho = 0.47694$, and is that value of x which corresponds to $y = \frac{1}{2}$ when $h = 1$. Therefore, in this case $h = \frac{0.47694}{25.56} = 0.019$, and

$$\log y = \log 0.019 - \log \sqrt{\pi} - (0.019)^2 x^2 \log e.$$

By giving suitable values to x the values of y are determined and the curve constructed. The computations are simple and the values of y laid off on section paper give the points through which the curve is traced.

In plate IV the curve marked I represents the independent battery. The ordinates were computed for every 5 yards up to 50 and then for every 10 yards up to 180. This and other principal curves are drawn full, while auxiliary curves are broken.

Having constructed curve I for the independent battery we easily pass to the curve for the typical battery, which is one of compound probability.

Taking the case where the volley is fired parallel to the principal axis of the battery and all pieces loaded with the same charge and similar projectiles and aimed with the same elevation, and azimuth, we may for simplicity in construction of curves, divide the battery into four subdivisions or subordinate batteries. The pieces are arranged in four lines of four mortars each. These lines are perpendicular to the principal axis and when the center of the battery is placed at the origin they intersect the axis of range errors at the errors +44.17 yards, +37.5 yards, −37.5 yards and −44.17 yards. These points of intersection are the[*] origins of range errors for their corresponding lines of mortars.

The origins of the first two lines are at O_1 and O_2, and since each of these lines represents but one-fourth the total number of shots fired, for the same errors as in curve I, the probability for each of these lines will be but one-fourth that for this curve. Laying off one-fourth the maximum ordinate of curve I at O_1 and O_2, we obtain O'_1 and O'_2, maximum points in the auxiliary curves. In like manner we construct ordinates in both directions from O_1, and O_2, at points 10, 20, 30 . . . whose values are one-fourth those for errors 10, 20, 30 . . . in curve I. Tracing curves through the points thus determined we obtain curves (II_1) and (II_2). These curves are the range-error probability curves for the two lines composing the front groups of the typical battery.

Since the larger part of the area of each of these curves is common to the other, it is necessary to embrace the area of both within a single curve. To do this we commence at their intersection and pass to the left and right applying the ordinates of the lower branches of the curves to those of the upper branches.

We thus add the probability of one curve to that of the other and by tracing a curve through the extremities of the resulting ordinates obtain (II*), which is the probability curve for the front groups of the typical battery. The two rear groups will give a curve identical with (II) and it may be drawn in its proper place using the ordinates of (II) in their proper order. Constructing (II′) it again appears that curves (II) and (II′) have a common area *A B C*. We again apply the ordinates of the lower branches to the same ordinates of the upper branches, obtaining (II,) which is the *probability curve of range errors for the typical battery.* This is a fundamental curve in our discussion and its characteristics deserve special notice. It possesses the same general properties as curve I. For a distance of about 60 yards on either side of the origin it is practically parallel to the axis of errors, and for distances beyond this in each direction, approaches this axis more slowly than curve I. Curves I and II intersect at errors ± 41 yards, at which points a small object would receive the same number of hits as far as range considerations are concerned. Within the range zone + 41 yards and — 41 yards, or a central zone of 82 yards the range probability will be greater for the independent battery than for the other; but beyond the limits of this zone in either direction the converse of this will be true. For range errors greater than ± 41 yards the ordinates of the typical battery curve exceed those of the other curve in a ratio increasing from unity at ± 41 to ten at the limits of the drawing.

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[*] In succeeding plates the pieces in front groups are considered collectively and the origin for the curve representing the 8 pieces is at the intersection of the line through the centers of the front groups with the principal axis; and similarly for the rear group. A curve constructed by this method for the groups just considered was so near (II) that it could not be shown on the drawing. This method being accurate and much simpler than the method above described is used in the following curves.

With the degree of range accuracy obtained in the group on June 27th, the typical battery for errors numerically greater than ± 41 yards, is superior to the independent battery in a high degree. The areas of the two curves within the limits occupied by the ship are directly proportional to the number of hits that may be expected within this range-zone. The relative areas of curves I and II included in the range-zones occupied by the ship in both transverse and longitudinal positions for various range errors of range-finder were carefully determined, and are arranged in the accompanying table for this plate. Having the mean of six ordinates of the curves covered by the width of the ship, these means are directly proportional to the areas of their respective curves and to the number of hits on the deck to be expected from each.

The ship used (the *Royal Sovereign*), is 380 teet long and 75 feet wide. In considering the number of hits on deck no allowance is made for the form of the deck which is taken in all cases as a rectangle 25 × 127 yards.

1. SHIP IN TRANSVERSE POSITION ACROSS THE LINE OF FIRE.

The ship's center is first supposed to be at the center of impact with broadside toward the battery and is supposed to move from this position always parallel to its first position, the center remaining on the line of fire or principal axis of the battery. The distances from the origin are given in column 1 and are the errors in range which may be made by the range-finder. Having considered the case where the center of impact and designated position of target coincide, we take up the actual case in which the center of impact is 20 yards short of this position of target.

It will be remembered that the range and position of the target for this firing were accurately known, having been determined under favorable circumstances, by triangulation with a long base, accurate instruments, and ample time for observation and verification. Had the method of determing the target's position been liable to uncertain errors such as would obtain in any system of range and position finding in action, the position for the target given here would be its designated position, while its real or actual position may be anywhere with respect to it, in accordance with the laws of error exemplified by the range-and position-finder range, and azimuth error curves.

An examination of the range-error curves of shot dispersion shows that an error of -20 yards in the position of the center of impact will materially affect the probability of hitting in comparison with no error, or other errors, such as -30, $+50$, or, $+100$ yards. The error -20 yards in the position of the center of impact produces the same effect upon the probable number of hits as if this point coincided with the designated position of the target, and the actual target were in error by $+20$ yards. In other words, errors in position of center of impact with respect to the designated position of the target simply move the origin of the curves one way or the other depending upon the sign of the error, and this has the effect of an equal increase or decrease in the range error of the range-and-position-finder.

Thus, for the present case, a range-finder range-error of $+50$ yards places the real target 50 yards beyond its designated position, and 70 yards from the origin of errors; but an error of -50 yards places the real target 50 yards short of its designated position and only 30 yards short of the origin. Hence, if we refer the origin to the designated position and take the algebraic difference between its co-ordinates and the respective co-ordinates of the actual target referred to the same point, the resulting co-ordinates will be the true ones, giving the position of the target with respect to the center of impact. To illustrate, we have $+50-(-20)=+70$, and $-50-(-20)=-30$. These numbers correspond to range errors of $+70$ or -30 yards when the designated position of target and center of impact coincide; and the number of hits, for range-errors of position of the ship ± 50, will be the same as for $+70$ or -30, under the supposition above made. The same applies to lateral deviations. Therefore, we may write generally

$$P_{\mathrm{R}}=f\,[E_{\mathrm{R}},\,(R_{\mathrm{e}}-I_{\mathrm{R}})];$$

$$P_{\mathrm{d}}=f\,[E_{\mathrm{d}},\,(P_{\mathrm{d}}-I_{\mathrm{d}})],$$

and treat range and azimuth errors of range-and-position-finder and center of impact, as simple range and azimuth errors. The results of this combination of errors in the present case are found in columns 6, 7, 8 and 9, and in columns 12, 13,14 and 15 of the table.

TABLE SHOWING RELATIVE VALUES OF P AND Q FOR GROUP GRAPHICALLY REPRESENTED IN PLATE IV.

90.0	5.7	23.0	0.53	23.45	1.91	10.59	19.20	40.29	21.0	25.60			30.34	37.10	1 : 0.80
92.5			5.58	21.55											
95.0	4.2	19.0	4.82	19.72	1.39	8.30	15.80	35.94							
97.5			4.05	17.88											
100.0	2.9	15.5	3.53	16.26	1.09	6.49	11.64	31.52					28.67	32.88	1 : 0.64
102.5			3.0	14.63											
105.0	2.6	12.8	2.61	13.22	1.0	5.75	8.77	27.37							
107.5			2.22	11.80											
110.0	1.4	10.0	1.91	10.59	0.73	4.80	6.53	23.48					21. 0	28.60	
112.5			1.60	9.38											
115.0	1.2	7.5	1.39	8.30	0.50	4.0	4.82	19.78							
117.5			1.18	7.22											
120.0	1.0	0.6	1.09	6.49			2.61	16.26							
122.5			1.0	5.75											
125.0	0.5	4.5	0.73	4.80			1.91	13.22							
127.5			0.50	4.0											
130.0	0.3	3.5					1.39	10.59							

Relative values only when lateral probabilities are equal for both batteries. For number of hits see small table in text.

$$P = \Sigma P = P^1 + P^2 + P^3 \ldots P^{16}$$

$$Q = \Sigma Q = Q^1 + Q^2 + Q^3 \ldots Q^{16}$$

and same for tables relating to following plates.

Columns 12, 13, 14 and 15 give the relative values for Q and P (notation used by Lieutenant Honeycutt) when the lateral probability for hits is equal for the two batteries. This for the group now considered and for longitudinal position of ship, is not generally true; and the numbers in the columns just mentioned must be multiplied by the percentage of lateral hits within the lateral zone covered by the width of the ship. This case will be treated later and is summed up in the small table of recapitulation in the text, which contains co-ordinates of the positions of the ship with number of hits to be expected in the different cases.

We have so far considered only range probabilities,—lateral probabilities now demand some attention. The curves 1, 2, and 3, are the lateral curves corresponding to I, II, and III. The firing at this range was so accurate laterally that the typical battery gives smaller probability near the principal axis than further out. The lateral curves of shot dispersion for the typical battery have a minimum point on the principal axis and maximum points corresponding to the centers of the groups of mortars on each side.

Taking the ship in transverse position as mentioned above, it will be observed that the ship with center anywhere within the lateral limits of the typical battery will practically cover the 100% lateral zones of both batteries. This lateral amplitude for the ship's center is considerably greater than the lateral probable error of the range-and-position-finder; but the limits can be increased by 10 yards on either side and yet introdnce no appreciable error as to the ship's length covering the 100% lateral zones. With the ship's center remaining within the lateral limits, ± 30 yards and moving in the transverse position to parallel positions, the following comparison of the two methods of fire is educed.

The ship extending across the 100%-zones of both batteries, for this case $P_d = 1$, and $P = P_R$. The relative values of P for this supposition (or the values of Q and P as they are designated in the inequality $Q^1 + Q^2 + . > P^1 + P^2 + . . .$), are given in columns 4, 5, 6, 7, 8 and 9, and the number of hits to be expected are obtained by dividing the numbers in these columns by 25.

Column 1 in the table gives the range-error of the range-and-position-finder, or the position the ship may occupy with respect to the position which will be designated by the range-finder, sent to the battery, and at which the battery will be aimed.

The ship being 25 yards wide the limiting ordinates for any position are 25 yards apart, and its center midway between them. Thus if the range error of the range-finder is + 100 yards, the areas of both curves between ordinates + 87.5 and + 112.5 must be determined. Columns 2 and 3 give the lengths of single ordinates of curves I and II respectively. Columns 4 and 5 give the means of six ordinates, three above and three below the one considered.

From curve 3, the lateral curve of range-and-position-finder errors, we obtain the following results: This curve gives the chances of the ship's center being within the ± 20 yards lateral zone as 3 to 2, and within the ± 30 yards lateral zone as 3.7 to 1. The limits ± 30 yards embrace 79% of all positions of the ship observed, and as the lateral probabilities for transverse position of the ship with center within these limits is equal for both batteries, the numbers in columns 2 to 8 inclusive are not affected by lateral considerations, and express directly the relative values of Q and P.

For positions of the ship outside the limits ± 30 yards, the values of P_d will not generally be equal for the two batteries. The independent battery will, for all positions of the ship's center between + 30 and + 63⅓, or — 30 and — 63⅓ yards, give more than 8 shots within the lateral zone occupied by the ship; and at the limits ± 63⅓ eight shots will fall within this zone. The area of the typical battery lateral curve shows that within the limits specified this battery will give fewer hits laterally than the other battery; but at the limits ± 63⅓ yards it will also give 8 hits. Therefore both batteries pass from 16 shots laterally at ± 30 yards to 8 shots at ± 63⅓ yards; but the laws of change in the number of hits to be expected in the two cases are different, being slightly in favor of the independent battery. The lateral probability of the typical battery is so great, however, that when combined with its corresponding range probability it will insure at least one hit, until the latter becomes so small as to render the product of the two probabilities by the number of shots less than 1.

The ship's center being in one of the lateral zones + 30, + 63⅓, or — 30, — 63⅓ yards, in transverse position, and moved up or down the axis of range errors, the number of probable hits will vary with the distance from the origin. From the higher range probability shown by curve I the independent battery will have the advantage until the range limits ± 40 yards are passed. At this point the two batteries are nearly equal in hits, but just beyond, the advantage passes to the typical battery. At the range limit of about 130 yards the advantage is with the typical battery in a proportion of 8 to 1. For all positions within the areas near the origin in which the independent is superior to the typical battery the latter will insure at least two hits, and for positions outside of this area the typical battery holds a most decided advantage. Therefore, while not concentrating shots unnecessarily, the typical battery gives a safe and practically uniform distribution of its projectiles over a large and especially a long area. The area near the origin just mentioned is not so thickly covered by the typical battery as by the other, but the columns in the table show about 2⅓ hits within the ± 40 yards limits, and that the chances are in favor of a hit even at 100 yards. On the other hand the independent battery gives over four hits at the origin, while the chances in favor of a hit does not extend beyond 75 yards, where the typical battery probability is more than 2.5 times as great. Two hits being considered sufficient in any case, the distribution by the typical battery, owing to the uncertain conditions pertaining to positions of centers of ship and impact, is in all respects superior to the other.

There are other considerations having an important bearing upon the problem, which, we believe, have been generally overlooked. Referring to the range-finder range-curve we obtain the following proportions:

Range probability of the ship's center being less than the specified distances from the origin.

10	yards	1:14	50	yards	1:2
12.5	yards	1:12	60	yards	1:18
20	yards	1:6.22	70	yards	1:1.21
30	yards	1:3.87	78.47	yards	1:1
40	yards	1:2.72	90	yards	1:0.8
41	yards	1:2.62	100	yards	1:0.64

The ship with its center at the origin will in the transverse position occupy a range zone of + 12.5 yds., — 12.5, which receives 27% of all the shots, by the independent battery; but the odds are 12 to 1 that the ship's center will not be found in this zone. The + 40, — 40 yds. range zone will receive 71¾% of all the shots, but the odds are 2.72 to 1 that the ship will not be found there; and again the + 78.47, — 78.47 yds. range-zone will by this method receive 96⅓% of all shots, but it is an even chance that the ship's center will not be found within it. Now the inexpediency of firing 27%, 71¾% and 96⅓% of all shots into zones in which the odds against the ship being found are respectively 12 to 1, 2.72

to 1, and 1 to 1, needs no demonstration. The typical battery, on the other hand, while safely covering these narrow range zones, distributes the remaining shots over a more extended area in which the ship is more likely to be found. *In this fact lies the claim of superiority for the typical battery*, which was made by General Abbot in his first and succeeding papers (see Defense of the Sea Coast of the United States, page 123, and *Journal of the U. S. Artillery*, volume II, p. 323).

2. SHIP IN LONGITUDINAL POSITION.

With the ship in longitudinal position or longer axis parallel to the plane of fire we consider the following series of positions:

First series of positions.

Center of ship at center of impact, and moved from this position to parallel positions along the principal axis of the battery.

1. Ship's center at the origin. The ship extends over the 91% range zone and 80% lateral zone of the independent battery. By this battery it would receive 72.8% of all shots or 11.65 hits. The odds are 14 to 1 that the ship's center will not be within 10 yards of the origin.

The relative range probabilities for the two batteries are, from columns 10 and 11 of the table, 69.40 and 55.80. From these we obtain 9⅓ hits by the typical vattery, but the ship's width covers a lateral zone of 18.9% from which, combining the two, we obtain 1.76 hits for the typical battery.

2. Ship's center at ± 30 yards in range, other things being the same as in 1. The lateral zones for both batteries are the same as before.

For this case the independent battery would probably furnish 10.45 hits, while the typical battery would give but 1.73.

3. Ship's center at ± 60 yards in range, other things same as 1 and 2. In this case we obtain 7.11 hits by the independent battery and 1.27 hits by the other.

4. Center of ship ± 90 yards from origin, other things the same as above. In this case we get 3.24 hits for independent battery, and 0.83 hits for the typical battery.

Second series of positions.

1. Ship's center ± 20 yards laterally, other conditions same as 1, first series of positions. In this case the ship will cover the 16.5% lateral zone of the independent battery and the 40% lateral zone of the typical battery. These percentages combined with the range probabilities give 2.40 hits for the independent battery, and 3.73 hits for the typical battery.

2. Ship's center ± 20 yards laterally and ± 30 yards in range. Independent battery, 2.16 hits; typical battery, 3.34 hits.

3. Ship's center ± 20 yards laterally and ± 60 yards in range. Independent battery, 1.46 hits; typical battery, 2.67 hits.

4. Ship's center ± 20 yards laterally and ± 90 yards in range. Independent battery, 0.67 hits; typical battery, 1.76 hits.

RECAPITULATION.

No. as given above.		Co-ordinates of center of ship.		Probable number of hits in 16 shots.		Odds against the ship's center being nearer the origin than distances assumed in		
		± Lateral.	± In range.	Independent battery.	Typical battery.	Column 2 (lateral).	Column 3 (in range).	
First Series.	1	0	0	11.65	1.76	2.12:1 That ship's center will not be within ten yards of origin.		14:1 That center will be less than ten yards from origin.
	2	0	30	10.45	1.73		3.87:1	
	3	0	60	7.11	1.27		1.80:1	
	4	0	90	3.27	0.83		0.80:1	
Second Series.	1	20	0	2.40	3.73	69:1 That ship's center will not be within twenty yards.		14:1 That center will be less than ten yards from origin.
	2	20	30	2.16	3.34		3.87:1	
	3	20	60	1.46	2.67		1.80:1	
	4	20	90	0.67	1.76		0.80:1	

Owing to the great lateral accuracy of this group the typical battery lateral curve shows a zone of minimum lateral probability at the principal axis of the battery, and two zones of maximum lateral probability corresponding to the lateral distance ± 20 yards, or to the right and left groups in the battery. This form of the curve accounts for the small number of hits by the typical battery when the ship's position is on the principal axis. As a rule these lateral zones of maximum and minimum probability do not exist as will be seen by examining the lateral curves of shot dispersion for this battery in the four following plates. The curves designated by 2 in these plates are either concave to the axis of lateral errors or practically parallel to this line.

It is evident that as the ship moves laterally outward in either direction from the ± 20 yard position it will again pass a point where the lateral probability will be the same as for the center, which even for a range error of 90 yards gives a probability of

0.83 of a hit. Therefore, beyond the lateral limits of the typical battery for some distance, the ship will, when 100 yards from the origin, be greatly in danger of being struck once, thus giving a lateral danger zone considerably wider than ± 32.5 yards.

Attention is also invited to the odds against the ship's center being less than 10 yards from the principal axis. A comparison of the columns in the above table of recapitulation is interesting. In this position of the ship, as in the transverse position, it appears that within short distances from the origin the independent battery gives a large number of hits and is apparently superior to the other battery, but the odds are so strongly against the ship being found within these distances of the origin that it amounts almost to certainty that it will not be found there.

The typical battery gives an almost uniform distribution of its 16 shots over the area considered, in such manner that it will be practically impossible for a ship in longitudinal position to enter it without being struck at least once. As shown above, the lateral limit of this area is greater than 20 yards, and with the extension of the ship beyond, when occupying limiting positions, embraces a rectangle at least 75 yards wide and 300 long. For the transverse position of the ship as above shown, with center within a lateral zone ± 25 yards, and for a range error of 100 yards, the typical battery has for extreme positions a probability of 0.81 of one hit. We may therefore conclude that if a ship's center for either position be so located that the center of impact of a volley from the typical battery can be placed within the lateral limits ± 25 yards and not more than 100 yards over or short, one hit is reasonably certain, while with the other battery the chances of being struck in these extreme positions are almost inappreciable. Where the independent battery is superior to the other shots are uselessly multiplied at the expense of other areas which remain unprotected.

The discussion has so far treated only transverse and longitudinal positions of the ship; for oblique positions the relative values of the two methods will be between those already given for the two limiting positions.

Plate V. Data.

Group fired at Fort Monroe, Va., August 10, 1896.

Nine shots: 1st shot (considered as ranging shot) omitted.

Mean range	6921.00 yards.
Mean of errors in range from center of impact .	54.25 yards.
Mean of errors in lateral direction from center of impact	19.00 yards.

TABLE SHOWING RELATIVE VALUES OF P AND Q FOR GROUP GR

	Ordinates to probabilities curves.				Ship in transverse position across the line of fire. Lateral percentage zones occupied by length of ship.							
	Single values.		Mean values of three.		Center of impact coinciding with designated position of target.				Center of impact 15.75 yds. right and 15.5 yds. short of designated position of target.			
					Lateral zones + 63⅓ and — 63⅓.		Lateral zones ± 79.08 and ± 47.58.		— error of range finder.		+ error of range finder.	
					99.2%	96.2%	86.7%	76.3%	(actual case.)			
Range error of range finder. 1	Independent battery. 2	Typical battery. 3	Independent battery. 4	Typical battery. 5	Independent battery Q. 6	Typical battery. P. 7	Independent batte.y. Q. 8	Typical battery. P. 9	Independent battery. Q 10	Typical battery. P. 11	Independent battery. Q. 12	Typical battery P. 13
0	118	98	117	98	116.1	94.3	101.4	74.8	98.8	73.0	98.8	73.0
5							101.0	74.4				
10	116	97	116	97	115.0	93.3	100.6	74.0	101.0	74.4	94.5	71.3
15							98.8	73.0				
20	113	95	112	95	111.0	91.4	97.1	72.5	101.0	74.4	88.5	68.3
25							94.5	71.3				
30	106	92	106	92	105.1	88.5	91.9	70.2	98.8	73.0	81.5	63.5
35							88.5	68.3				
40	99	88	98	87	97.2	83.7	85.0	66.4	94.5	71.3	73.7	60.3
45							81.5	63.5				
50	90	82	90	82	89.3	78.9	78.0	62.6	88.5	68.3	64.6	55.3
55							73.7	60.3				
60	80	76	80	76	79.4	73.1	69.4	58.0	81.5	63.5	55.5	50.0
65							64.6	55.3				
70	69	69	69	69	68.5	66.4	59.8	52.6	73.7	60.3	46.3	44.3
75							55.5	50.0				
80	59	62	59	62	58.5	59.6	51.2	47.3	64.6	55.0	38.6	38.5
85							46.3	44.3				
90	49	54	49	54	48.6	51.9	42.5	41.2	55.5	50.0	31.2	33.2
95							38 6	38.5				
100	40	47	40	47	39.7	45.2	34 7	35.9	46.3	44.3	24.7	28.2
105							31.2	33.2				
110	32	40	32	40	31.7	38.5	27.7	30.5	38.6	38.5	19.1	23 7
115							24.7	28.2				
120	25	34	25	34	24.8	32.7	21.7	25.9	31.2	33.2	14.3	18.1
125							19.1	23.7				
130	19	27	19	28	18.8	26.9	16.5	21.4	24.7	28.2	10.8	15.3
135							14.3	18.1				
140	14	22	14	22	13.8	21.2	12.1	16.8	19.1	23.1	8.2	12.
145							10.8	15.3				
150	10	17	11	18	10.9	17.3	9.5	13.7	14.3	18.1	6.1	9.
155							8.2	12.2				
160	8	14	8	14	7.9	13.5	6.9	10.7	10.8	15.5	4.4	6.
165							6.1	9.3				
170	55	10	6	10	5.9	9.6	5.2	7.6	8.2	12.2		
175							4.4	6.6				
180	35	7	4	75	3.9	7.2	3.5	5.7	6.1	9.3		

Target position corresponds to designated position of target, and in this discussion the
either side. In this case the designated position being 15 (15.5) yards beyond the center o
have coincided with the center of impact and the ship would then have occupied the maxi
this position would be — 15.

About 50 units in the column for transverse positions and about 10 in column for long
parative number of hits can be seen at a glance.

With center of ship on lateral lines ± 26 and occupying longitudinal position the sh
series of positions which the ship might occupy the relative values of Q and P are directly

Probable error in range	45.86 yards.
Probable error in lateral direction	16.06 yards.
Deviation in range of center of impact from designated position of target (short)	15.50 yards.
Deviation in lateral direction of center of impact from designated position of target (right)	15.75 yards.

Range-Finder.

Mean range	7039.37 yards.
Mean of errors in range	164.37 yards.
Mean of errors in lateral direction	9.01 yards.
Probable error in range	138.95 yards.
Probable error in lateral direction	7.62 yards.

Curves I, II, III, 1, 2, and 3 represent the same subjects as in plate IV. The accompanying table prepared for this plate contains relative values of *Q* and *P*. They are derived from the mean ordinates of curves I and II given in columns 4 and 5 for ship in transverse, and in 14 and 15 for ship in longitudinal position.

1. SHIP IN TRANSVERSE POSITION OR PERPENDICULAR TO PRINCIPAL AXIS OF THE BATTERY.

For this position, the ordinates in columns 4 and 5 are directly proportional to the areas of curves I and II, as the ship occupies successive positions parallel to the first position, with center at the distances from the origin given in column 1. We consider two series of positions, one with the center moving along the principal axis and the other on lines parallel to it at ± 15.75 yards from it. When the ship, in transverse position, moves with center on these lines, its length occupies lateral zones whose limits and percentages are found at the heads of columns 6, 7, 8 and 9. The mean ordinates in columns 4 and 5 multiplied by the percentages at the heads of the columns in 6, 7, 8 and 9 give the relative values of *Q* and *P* and the relative number of hits that may be expected by the two batteries. The number of hits for each may be determined by dividing the numbers in their respective columns by 50. By running down columns 6 and 7 it will be found that for small errors shown in column 1 the independent method gives higher probabilities than the other until errors ± 65 and ± 70 yards are reached when the superiority passes to the typical battery and remains with it for all errors beyond these values. The same may be said of columns 8 and 9 except that the change takes place between errors ± 80 and ± 85 yards.

The typical battery for this position of ship gives a more uniform number of hits for all distances, commencing with a sufficient number at the origin, and maintains the probability of at least one hit far beyond the limits of the other battery. For probable positions of the actual target, as indicated by the error curves of the range-and-position-finder the probability of hits is, as a rule, higher for the typical battery. The results should be carefully studied in connection with the numbers in columns 20 and 21. Columns 10, 11, 12 and 13 give relative values of Q and P, allowance being made for the deviation of center of impact from the designated position of the target. They show the effect of this center being 15.5 yards in range from the target as located by the range-finder. The numbers in these columns are obtained from 8 and 9 and refer to transverse position of the ship when moved with center on a line parallel to, but 15.75 yards from, the principal axis. When considering columns 10, 11, 12 and 13 the errors in 1 are estimated from the designated position of the target instead of the origin, and the values of Q and P are different according as the distance from this point is positive or negative.

2. SHIP IN LONGITUDINAL POSITION OR WITH THE LONGER AXIS COINCIDENT WITH OR PARALLEL TO THE PRINCIPAL AXIS OF THE BATTERY.

The mean ordinates to curves I and II for this position, as for the preceding one, and the method of finding the number of hits are similar to the one just described. In this case, however, the number of hits may be found by dividing the numbers in their respective columns by 10. The interpretation of columns 16, 17, 18 and 19 is similar to that given for the same case in plate IV, and the results are essentially the same; and we have in this, as in the preceding plate, a small area of superiority for the independent battery with a much larger area uniformly, but safely, covered by the typical battery with the superiority in its favor over the greater part. For all positions outside those given in the table the typical battery is superior to the independent in a marked degree.

Plate VI. Data.

Group fired at Fort Monroe, Va., August 13, 1896.

12 shots: 1st shot, ranging shot (omitted).

Mean range . . . . 7764.20 yards.
Mean of errors in range from center of impact . . 50.35 yards.

Mean of errors in lateral direction from center of impact	12.75 yards.
Probable error in range	42.56 yards.
Probable error in lateral direction	10.77 yards.
Deviation in range of center of impact from designated position of target (short)	45.63 yards.
Deviation in lateral direction of center of impact from designated position of target (right)	3.36 yards.

Range-Finder.

Mean range by range-finder	7828.10 yards.
Mean of errors in range	231.40 yards.
Mean of errors in azimuth, 6'.56, equal to	14.95 yards.
Probable error in range	195.57 yards.
Probable error in azimuth	12.64 yards.

From these data it will be observed that the dispersion of shots is somewhat less than in the preceding group for range of 6,921 yards. It follows that the firing was slightly more accurate, but the general conclusions drawn also apply to this group.

I. SHIP IN TRANSVERSE POSITION.

With ship in transverse position and center on the principal axis of the battery, the lateral zones covered by the ship's length are practically the 100% zones for both batteries. With the ship's center ± 20 yards from the axis the lateral zones become 99.2% for the independent and 92.7% for the typical battery. The products for the cases just mentioned are found in columns 6, 7, 8 and 9 of the table for this plate. The numbers in these columns divided by 25 give the number of hits to be expected in their respective columns.

The typical battery gives as before a more uniform probability as will be seen from the curves, and has a decided advantage for range errors beyond ± 67.5 yards and lateral errors ± 18 yards. The odds against the ship's center being within the ± 67.5 yards range zone are 4.4 to 1; and in favor of its being within the ± 18 yards lateral zone are 2 to 1. If, therefore, for this particular degree of accuracy the ship's probable positions were within a rectangle 135 yards by 36 yards symmetrically located with respect to the origin, the concentrated or independent method of directing the fire would be preferable; but the chances are 7 to 1 that the ship's center will not be found in this rectangle. The independent method in this case, as in those above, is superior over a small area around the origin where there is small probability of finding the ship. Taking this fact in connection with the small advantage over the small central area, if any advantage exists at all under actual service conditions, a ship will be more likely to be hit by fire from the typical battery. For the actual case, the designated position of the target being close to the principal axis of the battery (but 45.6 yards beyond the origin), no appreciable error will be introduced by omitting the small lateral deviation and using the central position instead; but the range deviation of this point being 45.6 yards, the effect upon probability of hits will be greater than for any actual case considered. The numerical values for this actual case are in columns 10, 11, 12 and 13.

2. THE SHIP IN LONGITUDINAL POSITION.

The results for the ship in this position are given in columns 16, 17, 18 and 19. They are similar to those for the ship in the same position for the preceding group. The number of hits to be expected may be found by dividing the numbers in the columns by 5. This division is easily performed in the mind while casting the eye over the columns.

By the typical battery we are practically certain of at least one hit when the ship's center is 150 yards, and for the transverse position 110 yards, from the origin.

As the probability of being struck for oblique positions will fall between the two limiting positions just considered, it would be difficult for the *Royal Sovereign* or a ship of her class to occupy any position with center anywhere within the above range limits and within a lateral zone of ± 30 to ± 35 yards, without being struck by a volley from the typical battery. This battery then covers so thoroughly a rectangle from 250 to 300 yards long by from 60 to 70 yards wide that great latitude is left for errors, still maintaining a high probability of the ship being struck. That this great latitude is necessary, we believe has been proved.

Plate VII. Data.

Group fired at Sandy Hook, N. J., May 2, 1895. Steel mortar No. 1. 5 shots. No target used.

Mean range	9285.00 yards.
Mean of errors in range from center of impact . .	36.00 yards.
Mean of errors in lateral direction from center of impact	14.62 yards.
Probable error in range	30.43 yards.
Probable error in lateral direction	12.40 yards.

Range-Finder.

Mean range by range-finder	9075.44 yards.
Mean of errors in range	191.22 yards.
Mean of errors in azimuth (lateral direction)	17.78 yards.
Probable error in range	161.66 yards.
Probable error in azimuth	15.00 yards.

In this group we have the probable error of range nearly as small as in the group for 5,975 yards. By comparing curves I and II the effect of this accuracy is apparent. They intersect at ± 47.8 yards and the two batteries will give equal results at about ± 50 yards. For positions of ship within these limits the independent battery gives more hits, while beyond these limits it will give fewer hits than the typical battery. The probability of the ship's center being 47.8 yards (or more) from the origin is to the probability of its being less as 5.34 to 1.

By comparing the range curves in this and plate IV with the same curves in V and VI, the difference between the former and latter sets, due to the greater accuracy of fire in the former, is apparent. Thus the less the range dispersion, the higher and steeper will curve I become and the nearer the origin will it intersect II. As greater accuracy gives greater differences between curves I and II, within the points of intersection, it also gives greater differences between them outside these points. This increased accuracy, therefore, shortens the range zone of superiority of the independent battery but makes its superiority more marked, while at the same time it lengthens the typical battery range zone of superiority and increases this superiority in a high degree. Therefore the greater the accuracy in the grouping of the shots, the greater the advantages of the typical over the other method.

Points of intersection of curves I and II in the different plates, in their respective cases, determine their maximum limits for the probable range-error of the range-finder, in order that the independent should, under all circumstances, be superior to the other method.

The lateral curves in this group are similar to those already described. For positions of the ship laterally the independent method will give the higher probability up to ± 20 yards, where curves 1 and 2 intersect; beyond this point the typical battery will be superior.

We here have results similar to those for preceding groups. For positions of the ship within the 100 × 40 yards rectangle the independent method will be superior, but for all positions outside of this rectangle the typical method will be more advantageous. The odds against the ship being located within the 100 × 40 yards rectangle are 8.34 to 1.

In this plate there is, in addition to the regular lateral curves, a lateral curve for four groups of mortars in line. The groups are 40 yards from groups on either side. A battery of this form fired by the parallel method gives an almost constant lateral probability over a zone of about 160 yards. The range curve for such a battery is practically curve I, or that for the independent battery. The dispersion of shots according to the parallel method by such a battery would distribute its shots over a zone more than five times the range-finder lateral 50% zone for this range. The lateral range-finder curve shows that 50% of the shots should fall within a zone 30 yards wide, and that 93% should fall within a zone 80 yards wide, in order to be in proportion to the probability of the ship being found in these zones. Such a battery if fired by the parallel method would distribute a large percentage of its shots over an area which would not under any circumstances contain the ship. Therefore the method of parallel fire for such a battery is clearly so erroneous that it should never be contemplated in a system of fire control.

From the comparative dimensions of the 25% rectangle of the range-finder errors for the five ranges considered, it is apparent that the shots should be distributed over long narrow areas. Therefore, uniform dispersion laterally and longitudinally so as to cover a square area is not only not required, but is positively forbidden by the conditions of the problem.

Plate VIII. Data.

Group fired at Sandy Hook, April 16, 1895. No. 1 Steel mortar. 10 shots. No target used.

Mean range	10754.40 yards.
Means errors in range from center of impact . .	49.96 yards.
Mean of errors in lateral direction from center of impact	25.48 yards.
Probable error in range	42.23 yards.
Probable error in lateral direction	21.54 yards.

Range-Finder.

Mean range	10401.00 yards.
Mean of errors in range	225.00 yards.
Mean of errors in azimuth 6′.56, equal to	20.55 yards.
Probable error in range	190.19 yards.
Probable error in azimuth	17.36 yards.

The mean longitudinal or range errors being essentially the same as for the group in plate VI, range curves I and II depending on these values, are practically the same as I and II, in that plate, and zones of equal percentage will correspond in the two cases. The range-finder range curve also is nearly identical with that in plate VI, so that range considerations in the two cases are practically the same. The lateral deviation curves, however, are flatter, giving wider 50% zones, and the 50% range-finder zone is wider than any one yet considered. Curves 1 and 2 intersect at ± 30 yards. Within this zone the independent method will be superior, but outside the limits ± 30 yards the typical parallel method will be most advantageous.

Range curves I and II intersect at ± 64.4 yards, within which the independent method will be preferable, but beyond these range errors the converse of this will obtain. It therefore follows that for the extreme mortar range of 10,754.4 yards the teachings of the shorter ranges hold true. For this group as for all the others considered, the superiority of the concentrated or independent method of firing mortars over the typical-battery method is confined to a small area around the center of impact which is safely covered by the latter method, while for all points outside this area the advantage is *greatly* in favor of the latter method.

The small areas referred to are not strictly rectangles but do not differ materially from those mentioned in each case, such as ± 30 × ± 64.4 yards in the present case. By laborious computations the boundary or dividing line between the areas representing superiority in the two cases could be traced upon the plat, but when done it would possess no practical value. The odds in this case against the ship being within the 60 × 128.8 yards rectangle are 6.5 to 1.

There are many other points of interest and value connected with the curves in the five plates presented as a means of illustrating this question, but it is found impossible to dwell upon all details incident to so comprehensive a subject. It is believed enough has been explained to enable the reader to study the curves with ease and that additional points of value not explained will suggest themselves.

* * *

The curves given in the five plates were constructed upon the supposition that the typical battery was fired in the direction of the principal axis.

This was done because it is assumed that this axis will be so directed as to bisect the principal field of fire, and that as a rule a large portion of the firing will take place approximately in this direction. Quoting the paper *Grouping of Mortars in a Battery*, "All around fire is not in general necessary" (page 5, paragraph 3), from which it would appear not generally desirable to fire directly to one flank.

In plate IV we have curve IV, which is the typical battery range curve when fired to one flank. This curve falls between I and II and intersects both at practically the same point. The range probabilities for this case are therefore between the probabilities for the independent and typical battery when fired in the direction of the principal axis, and their values will fall between those for curves I and II given in the tables; and the same general conclusions may be drawn from all the remaining sets of range curves.

Owing to the lateral accuracy of the groups at 5,975 yards the typical battery lateral curves for volley to one flank, would give a clear lateral dead zone of more than 40 yards in width, between shots from front and rear groups. The other plates would, when firing to a flank, give the following lateral results:

Plate V. A tendency to dead zone at the central point between front and rear groups, and a minimum probability about half the maximum on either side corresponding to center of front and rear groups.

Plate VI. An almost clear dead zone at the center, with a minimum point there, and maximum point at the points corresponding to centers of front and rear groups.

Plate VII. A low lateral probability at the center with maximum and minimum points as in VI.

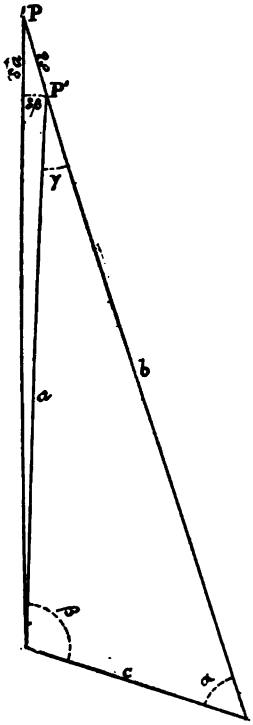
Plate VIII. Indicates an almost uniform lateral probability for all points within a zone of about 100 yards in width.

In cases therefore where a flank fire will be necessary with the typical battery some method of concentrating laterally will be necessary since neither a dead zone nor uniform lateral dispersion over a zone of 100 yards can be accepted. In fact this effect is not desirable in any case since it has been shown that wide lateral dispersion is not necessary, but rather the opposite is desirable in mortar fire. The remarkable agreement in all cases of the average lateral errors of shots and range-finder has already been pointed out, and if no other lateral errors than those of natural dispersion, center of impact and range-finder are introduced, the natural lateral dispersion of the independent method would be sufficient and this part of the problem could be left to take care of itself.

We have now considered the two extreme directions of fire from the typical battery. For directions of the line of fire between these two extremes the comparative values of the independent and parallel-typical method will be between those for the extremes as set forth in the foregoing discussion.

LATERAL ERRORS DUE TO RANGE ERROR OF THE RANGE-FINDER AND RELOCATION OF TARGET, FOR RANGE AND AZIMUTH FROM THE BATTERY.

The range error of the range-finder, as already shown for the five ranges considered above, has probable values varying from about 80 yards at 6,000 yards to about 195 at 11,000 yards. As the position of the range-finding station will in general be different from that of the battery the information determined by the range-and-position-finder for its own position must be sent to the battery and there converted into new data for this new position.



This operation will, when range errors exist, introduce an additional lateral error which in some cases may be important.

To illustrate, assume the following notation:

c = length of line joining center of battery with range finding station, here taken as 1,000 yards.

α = angle made with line c by line through actual target and range-finder, (the azimuth errors of the range-and-position-finder being small are omitted).

β = angle with line c made by line through designated position of the target and center of the battery.

γ = angle at designated position of target between lines from this point to center of battery and range-finder.

a and b are the sides forming γ; b is therefore the range given by the range-finder.

Assuming now that data sent from the range-finder to the relocator will be accurately converted by the latter instrument, we may determine the lateral errors which will be introduced by the range eror of the range-finder.

P in the figure is the true position of the target.

P' is the probable designated position.

$PP' = \delta b$ is then the probable error of the range-finder.

$PEP' = \delta\beta$ is the increment or decrement in azimuth due to PP'.

Assuming α to be constant in a given triangle we obtain by a simple deduction,

$$\delta\beta = \frac{3438\ c \sin \alpha \times \delta b}{a^2}.$$

For any range, as that of the 1st group, 5,975 yards, we substitute for δb 78.47, the probable range error of the range-finder, the value of c and the value of a, which for any assumed value of α corresponds to $b = 5{,}975$, and compute the value of $\delta\beta$.

These values are the probable lateral errors that will be made in aiming, owing to the incorrect range being sent to the battery. They are arranged in the accompanying table. The values of γ, it will be noticed, are all less than 12° and the majority are less than 5°. The small arc $P'D$ is practically a straight line and PDP' is practically a right-angle triangle with right angle at D. The maximum difference between PP' and PD will not be more than 2%, so that for all practical purposes the error in range will not be appreciably affected by relocation.

In the expression for the values of $\delta\beta$ it is apparent that for assumed values of α, or the range, which will be determined from the battery, $\delta\beta$ increases with $c\alpha$, and the probable range error of the range-finder; hence a reduction of c and selection of the range-finding station so as to give α values as small as possible, over the principal field of fire, will reduce this error to a minimum. As the range errors of the range-finder are frequently two or three times its probable error this source of lateral errors is of considerable importance. If the range-finding station be at the battery no error due to relocation will exist, but as this will as a rule be impracticable, some means of obtaining the azimuth from this point by direct view should be provided. To be able to determine the azimuth directly from the center of the battery would be a check upon other methods and an additional source of accuracy.

As shown above the lateral curves of the range-finder and shot dispersion for the five cases considered are remarkably similar. This similarity of curves shows that the natural dispersion of

Errors in Azimuth caused by Range Errors and Relocation.

α	γ	β	Range, yards.	Range from battery. yds.	Error in azimuth.	Azimuth or lateral error in yards.
30°	5° 44′	144° 16′	5841	5000	5′.4	8.1
	4 47	145 13	6845	6000	6′.6	11.4
	4 04	145 56	7848	7000	6′.9	13.8
	3 25	146 35	9285	8435	3′.9	9.7
	2 53	147 07	10755	9902	3′.3	9.3
60°	9° 58′	110° 02′	5424	5000	9′.3	13.5
	8 12	111 48	6564	6000	11′.5	21.6
	7 06	112 54	7696	7000	11′.9	23.8
	5 54	114 06	8887	8435	6′.8	17.0
	5 15	114 45	10418	9902	5′.8	17.4
90°	11° 30′	78° 30′	4899	5000	10′.8	16.2
	9 36	80 24	5916	6000	13′.2	23.1
	8 13	81 37	6955	7000	13′.7	27.4
	7 11	82 49	7937	8000	10′.5	26.3
	6 16	83 44	9285	9345	7′.8	20.8
	5 20	84 40	10755	10801	6′.7	20.7
110° 02′	9° 58′	60° 00′	5000	5424	9′.3	13.5
111 48	8 12	"	6000	6564	11′.5	21.6
112 54	7 06	"	7000	7696	11′.9	23.8
114 06	5 54	"	8435	8887	6′.8	17.0
114 45	5 15	"	9902	10418	5′.8	17.4
144° 16′	5° 44′	30° 00′	5000	5841	5′.4	8.1
145 13	4 47	"	6000	6845	6′.6	11.4
145 36	4 04	"	7000	7848	6′.9	13.8
146 35	3 25	"	8435	9285	3′.9	9.7
147 07	2 53	"	9902	10755	3′.3	9.3

shots by the independent method is practically in direct proportion to the probability of lateral errors of the ship's center, while the typical battery's lateral curve shows greater dispersion laterally than is required by the problem when errors due to relocation are not included. Taking these into account the typical battery gives a safe margin in lateral dispersion, but a lateral dispersion of 40 yards in addition to that incident to independent aiming of mortars may be questioned. However this may be, no increase in this battery's width can be introduced and the principal of parallel fire retained.

Taking the range curves of the typical battery they show by their form that the battery could be lengthened somewhat and still retain a practically constant and sufficient number of hits over a longer range zone.

We therefore conclude from the data before us that if any changes be made in the dimensions of the typical battery it should be made longer and narrower instead of the converse.

With accurate firing this battery now has a tendency to a lateral dead zone near the center, and when fired to one flank, this zone is too pronounced to be accepted with expectation of good results. The converse of this obtains for the range dispersion, showing that the curves could be considerably flattened and extended without reducing the probability of hits below a safe limit.

These suggested changes, it is believed, are in accord with the interpretation of the range error curves of the range-finder which are all flat showing nearly constant probabilities for different points. According to these curves the ship is almost as likely to be 50 or 100 yards from the origin as at this point, and such conditions do not justify concentrating more shots than just sufficient to do the work within any area, especially when such concentration is made at the expense of other areas in which the ship will be found with almost equal probability.

The form of the area which must be covered by the shots in a volley seems unmistakable. In case of a narrow channel where only small angular zones to right and left of the principal axis are to be protected the best form of battery would be four groups of four pieces each, arranged in column along this axis at intervals of from 40 to 50 yards and fired by the parallel method. The lateral dispersion in such a battery would be sufficient and the range dispersion would be such as to make each volley reasonably certain of at least one hit.

The groups used in this discussion clearly illustrate the relative chances of hitting a ship in longitudinal and transverse positions. To hit with longitudinal position seems comparatively easy; in the transverse position very difficult.

	Groups.				
Number of hits on Royal Sovereign. . .	1st,	2nd,	3rd,	4th and	5th.
For longitudinal position . . .	6	4	6	2	1
For transverse position	2	2	0	1	1

Ship in diagonal position in all cases receives from 1 to 2 hits. In the first three groups the ship's center is at the designated position of the target; in the others at the center of impact. The spaces greater than 25 yards between consecutive shots are numerous in all groups, showing how easily a ship in transverse position could lie in the midst of a group with small chance of being struck. In group at 7,764.2 yards the ship in longitudinal position receives 6 hits, but in the transverse position is not hit. Here, in a case of accurate observation, and correction made in each shot for the preceding error, the ship in this position was not hit in 12 successive trials.

Evidently one part of our problem in mortar fire is to disperse our projectiles in range, so that a war-ship of average size can not lie in a transverse position within a long range zone, either over or short of the designated position, without being hit; and the other part is to take a hostile ship whenever possible in longitudinal position. The first condition requires the projectiles to be distributed uniformly over a sufficiently long range zone, but close enough at all points to endanger the ship. If this can be done the lateral dispersion will take care of itself.

The other part of the problem will be fulfilled in cases where two batteries are available and so located that their lines of fire over the principal field will intersect at angles approximating 90°. A ship standing in transverse position to one would be nearly in the longitudinal position to the other, and practically certain of being struck.

THE GROUPING OF MORTARS IN A BATTERY.

(Title of paper officially before the Board.)

The views expressed in this paper demand some attention. Passing by the introductory remarks, we find on page 2 the beginning of the discussion relating to the typical and other forms of battery. On this page (paragraph 3) the method given for obtaining the center of impact is incorrect. The "results," mentioned as co-ordinates, are simply the algebraic sums of the co-ordinates of individual shots referred to the assumed origin and axis. These sums must each be divided by the number of shots in order to determine the co-ordinates of the center of impact.

The method of finding the 50% zones is also incorrect. A probability curve is in no wise necessary to obtain them; it being simply necessary to multiply the means of the lateral and longitudinal errors from the center of impact, by 0.8453 to determine the co-ordinates which limit the lateral and longitudinal 50% zones. The former product laid off on the axis of lateral errors, on either side of the origin, determines the position of the lines which, drawn parallel to the longitudinal axis, limit the 50% lateral zone, and in a similar manner the limiting lines of the 50% longitudinal zone are constructed. The area common to both zones is the 25% rectangle.

The zones obtained by the method in this paper are twice as wide as the 50% zones, and are in fact the 82¼% zones, and the rectangle formed is the 69.65% rectangle.

The comparison of 25% rectangles gives a measure of the accuracy of the piece including unknown errors made in aiming, but this method of treating the subject, as has been amply proved in the preceding discussion, furnishes no standard whatever as to the frequency of hitting a hostile ship.

The relative values of independent fire in general and of parallel fire applied to the typical battery have been considered in detail in our previous discussion.

It seems clear to the Board that the conditions of the problem of mortar fire demand that the projectiles of a volley be distributed over a long narrow rectangle whose average length for groups considered, with ranges from 6,000 to 11,000 yards is about 11 times its breadth. The dimensions of this rectangle are wholly independent of site, form of battery, or method of fire control. This area may possibly be suitably covered in different ways and by different forms of battery, but in all cases, except for parallel fire with the typical battery, would involve the use of complicated methods for transmission of information. The unity of command and simplicity of fire control in the typical battery resulting from parallel fire is a great advantage.

The problem of fire control in its simplest form, is a difficult one and any scheme which multiplies apparatus, operators or orders, or adds unnecessary complications, simply adds to the difficulty and increases the liability to failure.

The method of obtaining unity of command briefly suggested in this paper (Lieutenant Honeycutt's), by firing each group with independent elevations, charges and azimuths, would be extremely complicated in its details and is of doubtful application. The Board is not aware of any system of subdivision of areas which has proved successful or that is likely to solve this problem satisfactorily. In this matter great weight should be given to the views and experience of the designer of the typical battery who is a high authority on the subject of mortar fire.

The Board can add nothing to what he has written on the necessity for volley firing, unity of command, and many other details which are the result of his long and varied experience with mortar fire.

"One practical difficulty however was found to be inherent to the system, and it impressed itself upon my mind as something which should be corrected even with the large targets usual in field service, before all the efficiency possible could be secured. For use against so small a target as a ship this difficulty would become still more important; it is simply the impossibility of regulating the pointing by individual gunners when many pieces are directed at the same object. In gun practice the short time of flight enables each gunner to perceive where his own projectile strikes, and to regulate his pointing accordingly. With the long times of flight characteristic of vertical fire this is no longer the case. Shells are falling so thickly around the target that with a flight of many seconds he can no longer distinguish which is his own shot, and his aim may thus remain uncorrected because he imagines that he is doing much better than is really the case. Where, as in the case of a siege battery, the target remains immovable this difficulty may in a measure be overcome by determing and recording for future use the pointing of each piece separately; but against a target shifting position like a ship, I am satisfied that no dependence can be placed on individual pointing. One man must regulate the firing of a whole group of mortars to secure satisfactory results." (*Journal U. S. Artillery*, Vol. II, pp. 315–16.)

"In conclusion, I may be permitted to say that this type of battery was by no means developed by accident. The considerations which determined its forms were partly artillery and partly engineer; and of the two, the former predominated. One does not expend 40,000 rounds of mortar ammunition, and spend months in the trenches studying every possible means of increasing the precision of vertical fire, without having it impressed on the mind that group control must be secured before perfection can be expected. Bringing many pieces into close juxtaposition where no variation in pointing is needful, is thus one essential condition of rapid and effective service against shipping. On the other hand the enormous amount of heavy ammunition required in a sea-coast battery (1,700 tons to equip a sixteen-mortar battery with 200 rounds) introduces many troublesome engineer conditions. Moreover, long years have been required to secure ballistic data desirable for determining the proper grouping of the pits.

At last, however, the type stands completed; and it is my hope and belief that in the hands of artillery officers appreciating its theory and capabilities it will give a good account of itself in the next war." (*Journal U. S. Artillery*, Vol. V, pp. 323–24.)

The question of waste of ammunition is raised against the typical battery. The preceding discussion shows that the chances of hitting a ship are greater by this battery, when all things are considered, than by any other, and the battery and method of fire which gives the greater probability of hitting a hostile ship will be the most economical of ammunition.

THE VOLLEYS AT SANDY HOOK WITH THE TYPICAL BATTERY.

These volleys furnished the only reliable data yet obtained relating to the typical battery. While being cautious about drawing too many conclusions from a single experiment the following, we believe, are fair deductions from this practice.

The group of shots, as plotted, stand upon their own merits and are therefore entitled to greater weight than any rearrangement of them that can be made, and conclusions drawn from them are positive in their character, while the conclusions drawn from the rearrangement of the shots of these volleys to correspond to a battery of four pits in line, are tentative and uncertain. In the comparison made between the actual and rearranged volleys, we invite attention to the following irregularities: 1. In the volley at 3,000 yards, the comparison is made for the battery of pits in line supposed to be fired at 45° with the principal axis, while the typical battery *was* fired at an angle of 67° with this line. In the volley of 6,000 yards the former was supposed to be fired at 45° with the principal axis, while the latter *was* fired at an angle of 54° with this line.

As the most advantageous direction of fire for the typical battery is parallel to the principal axis, the comparison is decidedly unfair. As the principal field of fire will generally be in directions approximating to that of the principal axis, or say within 45° on either side of this line, the fairest comparison would be for both batteries firing parallel to this line. For this direction, which is the most important of all, the battery of pits in line fired by the parallel method will have its minimum and the typical battery its maximum efficiency.

2. Groups of mortars in the typical battery beyond the center of impact are placed short of this point in the plats for battery of pits in line and *vice versa*. This transfer of pits from front to rear and rear to front, distorts the dispersion for the battery of pits in line.

3. There are six doubtful shots in the 6,000 yards volley which occupy their correct positions in the typical plat, but in the other plat their places and values are unknown.

Summary of Comparison.

Typical Battery. Result of Investigation by Board of Engineers.				Battery of four pits in line, Result of Lieutenant Craighill's rearrangement of shots.			
		No. wasted on supposition that				No. wasted on supposition that	
Position of Ship.	Number of hits.	One hit will be sufficient.	Two hits will be sufficient.	Position of Ship.	Number of hits.	One hit will be sufficient.	Two hits will be sufficient.
3000 yards volley.							
Head on	2	1	0	Head on	6	5	4
Broadside to . .	3	2	1	Broadside to . .	8	7	6
45° to plane of fire.	2	1	0	45° to plane of fire.	6	5	4
45° to plane of fire.	5	4	3	45° to plane of fire.	8	5	4
No positions without hits.				No positions without hits.			
6000 yards volley.							
Head on	1	0	0	Head on	9	8	7
Broadside to . .	2	1	0	Broadside to . .	5	4	3
45° to plane of fire.	2	1	0	45° to plane of fire.	6	5	4
45° to plane of fire.	1	0	0	45° to plane of fire.	6	5	4
Axis of ship 20 to 35° to left of plane of fire.	0			No positions without hits.			

Special attention is also invited to the distribution of the projectiles by the typical battery, particularly at the 6,000 yards range. The assumed battery of pits in line, under the supposition of coincidence of centers of ship and impact and the method of rearrangement gives a large number of hits. The odds against coincidence of these two centers are so great that they amount to a practical certainty, and there is nothing gained by discussing a number of hits based on such an assumption.

From data already introduced it is an even chance that a center of impact under the given conditions will be less than 33 yards from the object aimed at, and at the range of 5,975 yards the center of impact, for 8 of the 9 shots fired in succession, corrections in aim being made for each shot, was 20 yards from the target. According to the range-finder range-error curve for this range, the chances of the ship being within 33 yards of its designated position is 0.2354 in 1, and the probability that both will be within the 33 yards range zone, referred to designated position of the ship is 0.1127 in 1, or about 1 to 8, and the chances that both centers will be in this zone and on the same side of the origin are 1 to 16. It has been clearly shown that the data upon which this reasoning is based are by no means derived from particular cases but express the general results of artillery practice.

No definite range is given for the volleys from the typical battery at Sandy Hook; they are called the 3,000 yards, and 6,000 yard volleys, but a range near 6,000 yards was evidently expected from the latter when the volley was fired. The mean range was 5,757 yards, leaving the center of impact 243 yards short of the intended range. Data above introduced would lead one to expect a great error of this kind where necessary corrections in aim had not been ascertained by trial shots.

The data at hand relative to 1st, 2nd and 3rd shots do not indicate that the whole of this error of 243 yards could have been eliminated by three trial shots. Referring to plate III we find that the average deviation of 3rd shots from target is about 80 yards. Assuming the same accuracy for this volley as obtained for the firing represented in plate III, and assuming three successive trial shots to have been made, the center of impact of the 6.000 yards volley could probably have been placed 80 yards from the 6,000 yard point. It is, therefore, a conservative estimate to suppose that three trial shots would have determined the necessary corrections by which the center of impact of the volley could have been placed about 80 yards from the point whose range was 6,000 yards.

In the rearrangement of shots for pits in line, although the group of shots is unduly extended as above, the extreme shots are found at — 83 and + 83 yards. Owing to the error in placing the center of the volley it is just possible that one shot, at most two, would have endangered an object at 6,000 yards.

The deviation of center of impact of this volley simply conforms to the general experience derived from all artillery practice and is an additional confirmation of the futility of basing any system of comparison upon the above assumption of the coincidence of centers of impact and target, and shows that results obtained upon such a basis are worthless.

VOLLEY AT 3000 YARDS.

In the rearrangement of the shots in this volley to correspond to the proposed battery of pits in line, the upper pit beyond the center of impact in the typical battery, is placed second in line from right to left, and there occupies a position short of the center of impact. The right-hand pit below is, in like manner, transferred from a position short to one beyond the center of impact and the two pits on the line through this point perpendicular to the line of fire are placed furthest from the center of impact. The effect of these changes upon the range dispersion of the proposed group of shots for battery of pits in line is shown by the following numbers:

	Extreme Length in Range.	
	Of battery.	Of shot dispersion.
Typical battery 45° to principal axis	95 yards	92 yards.
Typical battery (as fired 67° to principal axis)	80 yards	80 yards.
Battery of pits in line 45° to principal axis	53 yards	150 yards.

For battery of pits in line the length in range is two-thirds that of the typical battery fired at an angle of 67° with the principal axis, and the shot dispersion (as proposed) is nearly double that of the latter battery. For same range length as the typical battery the range dispersion of proposed battery of pits in line would be about three times that for the typical battery, a result which is clearly erroneous.

VOLLEY AT 6000 YARDS.

The same effect as above is noticeable in this volley, but it is not so marked and is modified by six doubtful shots.

	Extreme Length in Range.	
	Of battery.	Of shot dispersion.
Typical battery fired at 54° to principal axis	90 yards.	240 yards.
Battery of pits in line 45° to principal axis	53 yards.	165 yards.

The range dispersion for the proposed group is extended about one-sixth beyond what it would be with a battery range length equal to 90 yards, or that for the typical battery.

It is easily seen that the typical battery gives a more uniform dispersion over a longer range zone, and would endanger a ship in more positions than would result from the proposed battery fired by the parallel method.

A ship in transverse position would be out of danger from the proposed battery beyond the limits ± 83 yards. When errors of center of impact and range-finder are taken into account, these limits would be greatly reduced or would more probably vanish.

Between the extreme negative error — 83 and the center of impact, a ship could occupy two consecutive positions side by side without danger.

For positive errors of the range-finder the ship will be struck in any position up to + 83 yards, after which no danger exists. According to the range-finder range-curves the ship is as likely to be outside the ± 78.47 yard range zone as within it. The group of shots for the proposed battery gives 9, 5, 6, and 6 hits at the center, depending upon the direction of the ship's longer axis, and wholly neglects about half the area requiring protection.

In the typical battery for negative errors of the range-finder the ship in transverse position will be struck at — 110 yards and possibly be safe in two consecutive positions between this extreme shot and the center.

The ship, for positive errors of the range-finder, probably safe in three transverse positions, will be hit at + 133 yards, beyond which no danges exists.

THE PROPOSED BATTERY FOR FORT WADSWORTH.

Oblique direction of line of fire.

3000 yards.—There is no danger to a ship in transverse position beyoud + 42 yards, and between — 28 and — 67, the extreme negative shot, it can occupy positions in safety.

6000 yards.—Between shot at — 43 and the extreme negative shot there is a clear space of 80 yards in which the ship may occupy three consecutive positions without danger; the last negative shot is at — 123 yards, beyond which there is no danger. Between + 57 and + 90 and beyond + 90 the ship can lie without danger.

Directions of lines of fire coincident with principal axis.

3000 yards.—Beyond + 46 yards there is no danger to the ship. Commencing with — 31 yards there is a clear range zone of 46 yards with the extreme shot at — 77 yards and no further danger.

6000 yards.—At range errors + 52 yards a clear range zone begins, extending to + 87 yards, the extreme shot; between these limits and beyond + 87 yards a ship would be safe.

At range errors — 63 yards we find the beginning of a clear range zone extending to — 99 yards, the extreme shot; between — 63 and — 99, and beyond the latter no danger exists.

For the Fort Wadsworth battery, as proposed, we find as means of the four positions of the ship at the center of impact the following results:

	Oblique direction.	Front direction.
For 3000 yards range	4 hits.	6.5 hits.
For 6000 yards range	5¼ hits.	6.0 hits.

As there are enough projectiles in each volley to cover a range zone of more than ± 100 yards so effectually as to destroy a ship anywhere within these limits, provided they be dispersed in range according to the demands of the problem, it is the opinion of the Board that it would be more suitable to distribute the projectiles more uniformily along this range zone, as does the typical battery, instead of concentrating the greater portion of them in one spot and leaving dead zones, sometimes three times the width of the ship, and in some cases reaching to within 40 yards of the center.

For the oblique direction of the line of fire, the proposed Fort Wadsworth battery (according to the groups proposed) distributes its shots almost uniformly over lateral zones of 55 yards and 100 yards at the 3000 and 6000-yard ranges, respectively, and for the front directions over lateral zones, for these ranges, of 71 and 110 yards respectively.

This wide distribution laterally is not required and will result in a great waste of ammunition if such a scheme be put into execution.

It has been shown that the typical battery can be fired by the parallel method, and satisfactorily solves the problem except for extreme directions to a flank, a contingency not highly probable. It has also been shown that other forms of battery can not be fired by the parallel method with any claim to a satisfactory dispersion of the projectiles in accordance with the requirements of the case. With proposed forms there must be developed some means of aiming the pieces, not independently but having in view some accurate relation to one another, so that the correct form of area may be protected or covered by the fire. Whatever this method it is certain to be complicated, while the typical battery accomplishes the end in view in the simplest manner.

"Neither form of battery has any advantage over the other due to independent pointing of mortars; for all, carriages are provided with index rings and vernier pointers. Whether the mortars of the type battery will be pointed parallel or converging concerns artillery practice; whether the battery should be arranged to derive from parallel fire any advantage that is inherent in it concerns the engineer". (Letter for the Board of Engineers by the President of the Board, Colonel Robert, to General Craighill, in reply to paper entitled "Grouping of Mortars in a Battery," referred to this Board for an opinion upon subject matter.)

With respect to independent aiming the typical battery is the equal of any other form of battery, but at the same time may derive from parallel fire all the advantages incident thereto, such as unity of command and simplicity of fire control.

PROTECTION TO CANNONEERS.

This subject of protection is most exhaustively treated by General Abbot in his discussion and development of the typical battery. The Board is of the opinion that it can not do better than quote the following extracts from his writings on the subject.

"(3) Because vertical fire can not be silenced, even on land, when the mortars are properly covered. The artillery contest at the digging of the Dutch Gap Canal on James River in 1864 is a case in point. * * * This duel, and much other firing at Petersburg, convinced me that a mortar battery, well placed, well constructed, and well served, cannot be silenced. If this be true in respect to a land attack, how much more true is it in respect to a naval attack, where no target is presented for horizontal fire, and where vertical fire is not to be feared. In fine, ships may sometimes compel the silence of land guns, but they must endure vertical fire so long as they remain within range." (*Defense of the Sea-coast of the United States*, pp. 104-5. * * *

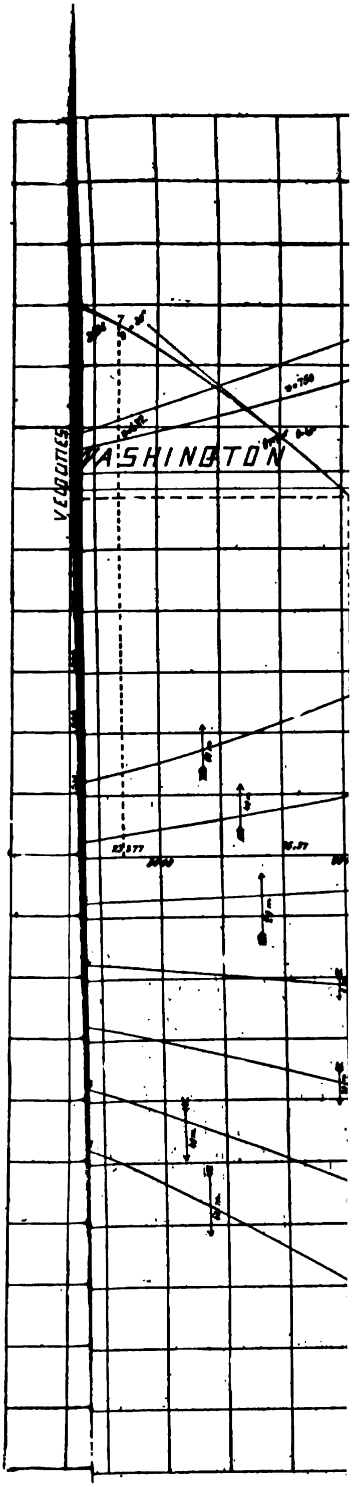
"(2) The mortar battery may usually be located where it is concealed from the enemy, and where no effective reply is practicable. This so materially reduce cost that the number of the mortars may be multiplied without extravagent outlay and their comparative lack of precision thus be corrected." (*Journal U. S. Artillery*, Vol. II, page 314). * * *

"The chief causes of bad practice are to be attributed * * * (5) to the excitement of action—although to this last little weight should be accorded in mortar practice against shipping, for the gunners will be covered so perfectly against any return, that the veriest coward should remain cool." (*Defense of the Sea-coast of the United States*, page 112.)

The Board of Engineers in their discussion of the paper entitled "Grouping of Mortars in a Battery" find no objection to the typical battery on the score of deficient protection to the cannoneers serving the battery.

In view of this fact and the opinions just quoted we are of the opinion that no important offensive principle should be sacrificed to provide against a fanciful or uncertain danger.

The phrase "typical battery" in this discussion is intended to embrace only the plan of the battery and parallel fire. The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engineering details, it is believed, can be satisfactorily worked. out, whatever may be the plan of the battery adopted.

CONCLUSIONS.

From the information presented to the Board and that collected by it on the subject of mortar fire, the Board is enabled to draw the following conclusions:

1. The area, which should be covered by volley or other firing of mortars in order to secure the maximum probability of hitting a hostile ship, is a long narrow rectangle whose length is several times its breadth.

2. The dimensions of this rectangle depend upon the range of the ship and the errors of the range-and-position-finder, and are wholly independent of plan of battery, site, and local conditions.

3. Owing to the great length of this rectangle compared to its breadth, uniform dispersion in range over a greater distance than that given by the independent method is practically sufficient.

4. Parallel fire cannot be efficaciously used over the principal field of fire by any form of battery except the typical battery, and should not be used with this form when its width of front between centers of groups exceeds 40 yards; when the fire is toward a flank lateral concentration will be necessary.

5. For the principal field of fire, parallel fire with the typical battery, with exceptions just mentioned, gives range and lateral dispersion in accordance with the above requirements.

6. Satisfactory range dispersion to meet these requirements cannot be obtained by independent aiming.

7. A system of fire control by which these requirements may be fulfilleed with individual mortars is possible, but such a system would embody serious complications which would endanger success, and the highest authority is against it.

8. Theories which neglect range-and-position errors in the location of the target, and deviations of center of impact from the same, are misleading and conclusions drawn therefrom are without practical value.

9. The probable number of hits upon the deck of a hostile ship will depend not only upon the shot dispersion but also upon the deviation of the center of impact from the designated position of the ship and the distance from this point to its true position.

10. The application of these principles to Lieutenant Honeycutt's proposition shows that the expression $Q^1 + Q^2 + \ldots > P^1 + P^2 + \ldots$ is not generally true, and that the relation between

Q and P depends upon circumstances. The circumstances showing superiority of the independent over the other method for the mortar practice considered in this report is found in the following summary.

SUMMARY.

Range of groups of shots.	$Q^1+Q^2+>P^1+P^2+$ only when ship is within the central rectangle, whose dimensions are given below. Center of impact and designated position of target supposed to coincide.		Size of rectangles in central position for which the independent method would be superior to the typical parallel method.	Odds against ship being located located within the rectangles described in preceding columns.	Superior limit for probable range-error of range-finder in order that independent should be superior to typical parallel method, expressed in per cent. of range.
	Yards, longitudinal.	Yards, lateral.			
1	2	3	4	5	6
5975	± 41.0	± 13	82 × 26	8 : 1	0.69%
6921	± 70.0	± 25	140 × 50	3.77 : 1	1.01%
7764.2	± 67.5	± 18	135 × 36	7 : 1	0.87%
9285	± 50.0	± 20	100 × 40	8.34 : 1	0.54%
10754.4	± 64.4	± 30	128.8 × 60	6.50 : 1	0.60%
8140	± 58.58	± 21.2	117.16 × 42.4	6.72 : 1	0.72%

Columns 2 and 3 give the longitudinal and lateral limits, within which the independent is superior to the typical-parallel method. Within these limits the probable number of hits by the latter method is sufficient, while beyond these limits the probable number of hits is largely in its favor.

Column 4 gives the dimensions of the rectangles corresponding to the limits in 2 and 3, and 5 gives the odds against the ship being found there. The numbers in columns 2 and 3 are the superior limits of the probable errors for the range-and-position-finder in order that the independent may for all circumstances be equal to the other method. The averages in the last line of the table indicate that the mean of the probable errors of the range-finder for ranges from 6000 to about 11,000 yards must not exceed 0.72 of one per cent of the range in order that the above condition may be fulfilled. The table is based on the assumption that the designated position of the target and the center of impact coincide,—the most favorable case for the independent method. Column 5 shows that even under this most favorable supposition the independent method will be inferior in probable number of hits to the typical parallel method, in 6.72 times out of 7.72, or in 672 out of 772. Improvements in results of range-and-position-finder will operate to the advantage, and improvements in mortar practice to the disadvantage of the independent method.

Having given so much time to the study of the subject of mortar fire it seems proper for the Board to make the following suggestions:

1. That harbors defended by mortar batteries be divided into a suitable number of range zones, say from five to ten; that the most suitable angles of elevation for the limiting range lines of zones be selected; that the kind and weights of powder charge corresponding to these elevations be definitely determined and that the method of passing, by change of elevation, from one range to another within a zone be prescribed.

2. Since the ammunition allowed for mortar practice is limited, and since the data increase in value with the number of shots fired under similar conditions, it is believed that all the mortar practice at any post should, if practicable, have not less than 8 or 12 shots at the same range in any one day.

3. That the probable errors of the official range-and-position-finder be determined under average service conditions, both for vessels at anchor and in motion.

4. That from the probable errors of the range-finder, the resulting errors in azimuth at the battery due to relocation be computed and tabulated.

5. That all sources of error relative to gun and mount, be investigated and the errors determined as soon as practicable.

6. That in all mortar firing due attention be paid to the question of trial shots with a view to the determination of the number required under given circumstances and the most advantageous manner of using them, to secure accurate volley firing in action.

7. In order to determine accurately the exact range of trial shots an observer should, if practicable, be stationed at right angles to the line of fire since the information is essential to secure accurate fire in time of action.

8. That means of measuring azimuth directly from the center of the battery be provided whenever practicable.

9. That the azimuth of landmarks and stationary objects such as false buoys, with distance to mid-channel, be carefully determined and located so that they may be used both in determining the correction deduced from trial shots and also to furnish the battery with the necessary data to continue its fire in case the general range-finding system should break down.

The Board acknowledges its obligation to the Chief of Ordnance, the Chief of the Weather Bureau and Mr. E. S. Dana, editor *American Journal of Science* for valuable information relative to this report.

ON THE SIZE AND SHAPE OF POWDER GRAINS.

A study by Nikolaus Ritter von Wuich, Colonel of Artillery and Superintendent of the Technical Military Courses of Instruction.

My study, entitled "Investigations on the pressure relations in the combustion of powder in closed vessels," which appeared in the *Mittheilungen* for 1888, constituted the basis for the succeeding essays entitled "The Problem of the movement of the Projectile in the bore," and "Contribution to the Theory of the so-called static Pressure-gauges," which also appeared in the *Mittheilungen* for the years 1894 and 1896, respectively.

In this paper I propose to go back to the first of the above-mentioned studies, in order to attempt the solution of the question of powder grain dimensions, which is of such great importance in the construction of fire-arms, or at least to call attention to and induce an interest in its solution, since—so far as I know—this question has not as yet been settled, although, the knowledge of the fact that "strictly speaking for each gun or fire-arm there is a powder, which in constitution, form and size of grain, is more suitable than any other," has, as the result of experience, become public property in the technical artillery world.

Whereas, a few decenniums ago, there was but *one kind* of military powder, and that was regarded as *noli me tangere*, before which the gun constructor bowed down, *i. e.* was compelled to make all possible concessions to it, a fact which contributed not a little to delay the development of the gun question—whereas, in other words, there was no powder question at all a few decenniums ago, and powder was not considered a *part* of the fire-arm organism; to-day, on the other hand, powder is regarded as an important internal organ of a fire-arm, since experience teaches that *the probability of the existence of a weapon with a certain desired effectiveness depends upon our finding the proper powder for it.*

It is generally known what course the development of the powder question took in the case of the *old residue powder:* grains of various *sizes* were tried, often of special *forms*, the *constitution* of the powder mass was changed (brown powder), also the *interior structure* of the grain (progressive powder). From this transformation process resulted the *cubic grain* of various sizes, as well as differences in constitution of the powder itself, but the powder mass had a relatively small power of resistance to the shock of the powder gases, which interfered considerably with the realization of the results expected from the theoretically correct exterior form and interior structure.

This is all quite different in the *modern powders*, which are composed of tough materials, less sensitive to the shock of the powder gases, and which, as shown by experiment, burn in the bore exactly as the theoretical worker in powder had to assume they would in the case of the old powders, in order to apply his analytical apparatus; now artifical forms are justifiable, and indeed they are used too (*e. g.* hollow-cylinder grains), but the phenomena are much simpler then in the old powder.

The question which I will attempt to answer, or to which I desire to attract attention, may be stated thus:

Assuming that, by means of carefully conducted experiments, the most appropriate powder grain for a given fire-arm has been found, what will be the dimensions of the grains for another fire-arm, in order that the powder may again give the best results?

It is therefore a question of applying appropriate dimensions (determined in a particular case) to new conditions, the former furnishing a basis for the experiments relating to the latter, and thus narrowing the scope of these experiments considerably.

It may be objected to this that it is only a kind of relative solution, and that an *actual* solution of the problem can only be an absolute, *à priori* solution.

In my opinion there is no such thing in the natural sciences as an absolute solution, *i. e.* one entirely independent of observation and experience; observation and experience are the sources of science, whose province it is to build up on the sure foundations laid by experience (by experiment),—hence, in the case before us, to derive some benefit from the knowledge which we have acquired so painfully for particular conditions and relations.

Two powders are equally rapid when in a given time, t, the relation of the consumed portion of the charge to the entire charge remains the same.

For this relation, which we will designate by a, I have already introduced the expression *combustion function*; the first thing to be done, then, is to find the expression for this function; and in this connection I will widen the scope of the first study by including in the sphere of investigations besides the spherical or cubic grain, also the parallelopipedon in general and the solid and hollow cylinder.

From the differential quotient $\frac{\delta a}{\delta t}$, the so-called velocity of emission, *i. e.* the instantaneous rapidity with which the gases are given off, may be determined, since the differential quotient gives the amount of the charge that burns off in the unit of time, the rapidity of the gas emission being constant for this time interval.

For *equal rapidity* the value of $\frac{\delta a}{\delta t}$ must, of course, be the same.

Let us pass to the determination of the *combustion function*, assuming that *all* the grains (supposed to be of homogeneous composition) of a powder charge are inflamed *at the same time* over their *entire* surface, so that, in expressing the conditions, the factor in numerator and denominator expressing the *number of grains* in the powder charge, disappears, and we need consider only *a single* grain; in a similar way, in the relation of *weights* the specific gravity of the powder disappears, hence, we can limit ourselves from the first to the relation of *volumes*.

δ is the symbol for the thickness of the layer consumed in the time t; we will first express, for the forms of grains previously referred to, a as a function of δ.

Spherical form.—If d represent the diameter of the grain, its volume is:

$$\tfrac{1}{6} d^3 \pi;$$

and since the diameter is diminished by 2δ in the time t, the volume of the grain becomes

$$\tfrac{1}{6} (d - 2\delta)^3 \pi$$

and the volume of the consumed portion of the grain

$$\tfrac{1}{6} d^3 \pi - \tfrac{1}{6} (d - 2\delta)^3 \pi,$$

which, divided by the volume of the grain, gives:

$$a = 1 - \left(1 - 2\frac{\delta}{d}\right)^3. \qquad (1)$$

Parallelopipedon form.—If a, b and c represent the absolute lengths of the sides meeting in one solid angle, then $a\,b\,c$ is the volume of the grain, and

$$(a - 2\delta)(b - 2\delta)(c - 2\delta)$$

its volume after the time t.

The consumed volume is

$$a\,b\,c - (a - 2\delta)(b - 2\delta)(c - 2\delta),$$

$$\therefore \quad a = 1 - \left(1 - 2\frac{\delta}{a}\right)\left(1 - 2\frac{\delta}{b}\right)\left(1 - 2\frac{\delta}{c}\right). \qquad (2)$$

Cubic form.—The expression for this is given by equation (2) when $a = b = c$, or from (1) by placing a for d, which is naturally so, as the cube is a form related to the sphere.

We therefore obtain

$$a = 1 - \left(1 - 2\frac{\delta}{2}\right)^3. \qquad (3)$$

Parallelopipedon form with square base.—The expression for this case results from (2) by placing $a = c$,

$$\therefore \quad a = 1 - \left(1 - 2\frac{\delta}{a}\right)^2 \left(1 - 2\frac{\delta}{b}\right). \qquad (4)$$

If b (the height) is small as compared with a, the grain may be regarded as a square thin plate, or sheet, which is a form much used at present.

Solid cylinder form.—If d designate the diameter of the base and h the height, the volume is

$$\frac{d^2 \pi}{4} \cdot h,$$

which, in the time t, becomes

$$\frac{(d - 2\delta)^2 \pi}{4} (h - 2\delta),$$

and

$$a = 1 - \left(1 - 2\frac{\delta}{d}\right)^2 \left(1 - 2\frac{\delta}{h}\right), \qquad (5)$$

which may also be derived from (4) since the cylinder and the parallelopipedon with square base are related geometrical forms.

A glance at the preceding equations shows that (1), (3), (4) and (5) result from (2) by proper specialization.

Hollow cylinder form.—Let d_i be the diameter of the interior, d_a the diameter of the cylinder and h its height, then the original volume is

$$(d_a^2 - d_i^2)\frac{\pi}{4} \cdot h,$$

and at the end of the time t

$$[(d_a - 2\delta)^2 - (d_i + 2\delta)^2]\frac{\pi}{4}(h - 2\delta), \text{ and}$$

$$a = 1 - \left(1 - 4\frac{\delta}{d_a - d_i}\right)\left(1 - 2\frac{\delta}{h}\right). \qquad (6)$$

The expressions (1) to (6) are capable of various useful transformations.

For the solution of *problems of motion* it is advantageous to retain δ as fundamental variable, and to carry out the indicated multiplications, as was done in the initial study on problems of motion above referred to.

It will readily be seen that the combustion function α may in general be represented by:

$$\alpha = \beta_1 \cdot \delta + \beta_2 \cdot \delta^2 + \beta_3 \cdot \delta^3;$$

the expressions for the coefficients β_1, β_2 and β_3 are given in the following table:

Form of Grain.	β_1	β_2	β_3
Sphere.	$\frac{6}{d}$	$-\frac{12}{d^2}$	$\frac{8}{d^3}$
Parallelopipedon.	$2\left(\frac{1}{a}+\frac{1}{b}+\frac{1}{c}\right)$	$-4\left(\frac{1}{ab}+\frac{1}{b}+\frac{1}{bc}\right)$	$\frac{8}{abc}$
Cube.	$\frac{6}{a}$	$\frac{12}{a^2}$	$\frac{8}{a^3}$
Parallelopipedon with square base.	$2\left(\frac{2}{a}+\frac{1}{b}\right)$	$-4\left(\frac{1}{a^2}+\frac{2}{ab}\right)$	$\frac{8}{a^2b}$
Solid cylinder.	$2\left(\frac{2}{d}+\frac{1}{h}\right)$	$-4\left(\frac{1}{d^2}+\frac{2}{dh}\right)$	$\frac{8}{d^2h}$
Hollow cylinder.	$2\left(\frac{2}{d_2-d_1}+\frac{1}{h}\right)$	$-\frac{8}{(d_2-d_1)h}$	0

For the investigations we have in view the time t must be introduced as fundamental variable, which—as was done in my study on the closed vessel—is done by indicating the dependence of the value δ on the time.

If c is, in general, the variable velocity of combustion of the powder, then:

$$\delta = \int_0^t c \,.\, dt. \qquad (a)$$

If c is assumed as directly proportional to the instantaneous pressure p, and inversely proportional to the specific gravity σ (or to the density) of the powder itself, we may write

$$c = c_0 \cdot \frac{p}{\sigma},$$

and (a) becomes

$$\delta = \frac{c_0}{\sigma} \int_0^t p \,.\, dt. \qquad (a_1)$$

c_0 is the *quality coefficient* and characterizes the physical properties, hence the internal constitution of the preparation.

Now, in order to take account of the conditions in the bore—and that is the corner-stone of my theory—I will take the liberty to introduce, in place of the *variable* pressure p, the *mean* pressure p_m in the bore as a constant, when (a_1) becomes

$$\delta = \frac{c_0 \cdot p_m}{\sigma} \cdot t. \tag{7}$$

In equation (7) the value of p_m is to be substituted. If we represent by W the weight of the projectile, by g the acceleration due to gravity, by V the initial velocity, by $q = \frac{\tilde{\omega}}{W}$, the ratio of the weight of the charge to the weight of the projectile, then the work done by the gases is expressed with sufficient accuracy by

$$(1 + \tfrac{1}{3}q) \cdot \frac{W}{2g} V^2.$$

If x_0 represent the distance passed over by the projectile up to the muzzle, and w the area of the section of the bore, the work of the mean pressure—supposed constant—is

$$p_m \cdot w \cdot x_0.$$

From this the following equation results

$$(1 + \tfrac{1}{3}q) \cdot \frac{W}{2g} V^2 = p_m \cdot w \cdot x_0,$$

or, if we neglect $\frac{1}{3}q$ as compared with 1 :

$$\frac{W}{2g} V^2 = p_m \cdot w \cdot x_0,$$

from which we obtain :

$$p_m = \frac{1}{x_0} \cdot \left(\frac{\frac{W}{2g} V^2}{w} \right). \tag{8}$$

The part in parenthesis is the *specific cross-section energy at the muzzle* (initial cross-section energy) ; and if we represent this by e_s we have

$$e_s = \frac{\frac{W}{2g} V^2}{w} = \frac{W_s}{2g} V^2, \tag{9}$$

in which W_s represents the *specific cross-section load;* hence, we may write, from (8):

$$p_m = \frac{e_s}{x_0}, \tag{8_1}$$

and (7) becomes

$$\delta = \frac{c_0}{\sigma} \cdot \frac{e_s}{x_0} \cdot t. \tag{7_1}$$

Note.—The maximum pressure p_{max} is a multiple of the mean pressure, hence we may write

$$p_{max} = \gamma \cdot p_m.$$

The factor γ—which is, of course, greater than 1—may be readily determined theoretically, as we will show by using the simplest formulae of the problem of motion.

In the above mentioned study on the problem of motion we found, under the assumption that the powder charge is entirely decomposed before the projectile begins to move,

$$\frac{W_s}{2g} \cdot V^2 = p_{max} \cdot \frac{l}{m-1}\left[1 - \left(\frac{l}{l+x_0}\right)^{m-1}\right]$$

as the *empirical potential law of energy* and

$$\frac{W_s}{2g} \cdot V^2 = p_{max} \cdot l \cdot \log \frac{l+x_0}{l} {}^*$$

as the *isothermal law of energy.*

From (8) we have

$$\frac{W_s}{2g} V^2 = p_m \quad x_0;$$

and by placing this expression equal to those found above, we obtained the the desired relation between p_{max} and p_m, and hence the factor γ.

Of course, we must not expect useful results from the relations obtained, since the assumption we started with is not quite true; we merely intended to sketch the manner of procedure which theory must take in order to obtain the relation between p_{max} and p_m.

The value of δ is now introduced into formulas (1) to (6).

It will be sufficient (in order to obtain the formula for the form and dimensions of the grains) to make the substitution in one of the formulas, *e.g.* in formula (2), which is of a more or less general nature, since the formulas (1), (3), (4) and (5) may then be derived from it by specialization.

If we substitute the value of δ from (7_1) in equation (2), we have for the *combustion function* the expression:

$$a = 1 - \left(1 - 2\frac{c_0}{\sigma} \cdot \frac{e_s}{x_0 \cdot a} t\right)\left(1 - 2\frac{c_0}{\sigma} \cdot \frac{e_s}{x_0 b} t\right) \cdot$$
$$\left(1 - 2\frac{c_0}{\sigma} \cdot \frac{e_s}{x_0 \cdot c} t\right). \tag{b}$$

Now, if we consider another *similar* grain (since grains of different form, on account of the difference in the process of gas development, cannot be compared), characterizing the relations for the new grain by the subscript "1," we have:

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* The formulas contained in the study are here specialized for the muzzle; the expression p_{max} is substituted for p_m of the study and w placed $= 1$; l is the length of the combustion space, when its cross-section is that of the bore.

$$\alpha_1 = 1 - \left(1 - 2\,\frac{c'_0}{\sigma_1}\cdot\frac{e'_s}{x'_0\cdot a_1}\cdot t\right)\left(1 - 2\,\frac{c'_0}{\sigma_1}\cdot\frac{e'_s}{x'_0\cdot b_1}\cdot t\right)$$
$$\left(1 - 2\,\frac{c'_0}{\sigma_1}\cdot\frac{e'_s}{x'_0\cdot c_1}\cdot t\right),$$

and if we place the relation of the *homologous* dimensions,

$$\frac{a_1}{a} = \frac{b_1}{b} = \frac{c_1}{c} = \varepsilon, \text{ then}$$

$$\alpha_1 = 1 - \left(1 - 2\,\frac{c'_0}{\sigma_1}\cdot\frac{e'_s}{x'_0\cdot a\cdot\varepsilon}\cdot t\right)\left(1 - 2\,\frac{c'_0}{\sigma_1}\cdot\frac{e'_s}{x'_0\cdot b\cdot\varepsilon}\cdot t\right)$$
$$\left(1 - 2\,\frac{c'_0}{\sigma_1}\cdot\frac{e'_s}{x'_0\cdot c\cdot\varepsilon}\cdot t\right). \qquad (c)$$

Comparing the expressions (*c*) and (*b*) we see that *the value of the combustion functions α and α_1 will always be equal when the condition*

$$\frac{c_0}{\sigma}\cdot\frac{e_s}{x_0} = \frac{c'_0}{\sigma_1}\cdot\frac{e'_s}{x'_0\cdot\varepsilon}$$

is fulfilled.

The dimensions of the grain must be determined with reference to the first stages of the movement of the projectile, since it is a question of diminishing the detonating tendencies of the powder, or, in other words, to reduce the maximum pressure, which alone renders possible, in many cases, the construction of the tube with given conditions of action and a fixed weight.

By *diminishing* α the detonating action is reduced: for this means that in a given given time a *relatively smaller* portion of the powder charge is consumed.

Formulas (1) to (6) show, if the value ot δ from formula (7) be substituted therein, that with a given p_m and t, the value of α becomes smaller, the smaller c_0, and the greater σ and the absolute dimensions* of the grain are made, from which it follows that these measures are necessary, in case an *increase* of p_m is desired, in order that the value of α may not change.

These are well-known facts, which have been established by observation and experience; and it is also well-known that in the measures for lowering the detonating action of the powder an increase in the powder charge with a given length of tube, or an increase in the length of tube with a given powder charge, or, lastly, both these measures, will be necessary to obtain a *particular initial velocity*.

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* In hollow grains the thickness of the walls must, of course, be increased.

Finally, it should be noted that, to obtain the *greatest possible initial velocities*, *i. e.* to utilize fully the powder charge, and we are not limited within narrow bounds as regards weight and length of tube, the lengthening of the tube is a proper and recently frequently employed (with flat trajectory fire-arms) means.

The striving after the full utilization of the powder charge explains why the gun constructor makes the tube so long that the powder charge is completely consumed in it, or, mathematically expressed, why the gun constructor regards the length of bore as a function of the powder grain dimensions; but it would be entirely erroneous and would lead to serious absurdities, to start with a fixed length of tube, and then give the grains such dimensions as to cause the powder charge to be entirely consumed in the bore, *i. e.* to regard the grain dimensions as a function of the length of tube.

If in the equation

$$y = f(x)$$

we determine x, *i. e.* reverse the equation, and obtain

$$x = F(y),$$

the two equations express the same thing in form, but not in principle.

If we have a tube of fixed length, the powder is to be constituted so that a definite permissible maximum pressure is not passed, in which case it may easily and probably will happen that the powder grain receives dimensions such that it cannot be entirely consumed in the bore, but this we will have to endure under the circumstances.

I do not see in the ejection of grains only partially consumed anything so entirely irrational as is commonly represented; and this study affords me a favorable opportunity to express my feelings on this subject.

Since the dimensions of the grain must be regarded as entirely independent of the path travelled by the projectile, x_0 (or x'_0) in the formula for the calculation of these dimensions must disappear, which is effected in the last formula obtained by assuming $x_0 = x'_0$.

The relation of the homologous dimensions, in case of equal detonating action of the powder, is then expressed by:

$$\epsilon = \frac{c'_0}{c_0} \cdot \frac{\sigma}{\sigma_1} \cdot \frac{e'_s}{e_s}\ * \qquad (10)$$

If the powder itself has the same composition, then $c'_0 = c_0$ and equation (10) becomes:

$$\epsilon = \frac{\sigma}{\sigma_1} \cdot \frac{e'_s}{e_s} \qquad (10_1)$$

Were the values of c_0 and c'_0 for powders of different constitution (*e. g.* residue powder and smokeless powder) known, we could readily pass by means of equation (10) from one kind of powder to another; unfortunately, the values of c_0 (or c'_0) have not been *definitely* determined and extensive experiments are still required to effect this.

I will give a simple example to illustrate the application of formula (10_1) which states that: *in case of powders of similar constitution the homologous dimensions are directly proportional to the specific*

Elements of the Gun.	Field Gun.	Siege Gun. M. 80.			Coast Gun.
	(9)		(15)		(15)
Caliber, cm	8.7	12	14.9	18	14.9
Weight of projectile (shell) kg.	6.36	16.7	31.9	56.4	42.5
(Greatest) Initial velocity m.	448	516	482	252	549
Average density of the powder	1.680	1.740	1.740	1.680	1.730
Initial specific cross-section energy e_s, kgm.	1.095	2.004	2.167	717.5	3.745
Ratio $\frac{e'_s}{e_s}$, of the specific cross-section energies .	1	1.831	1.979	0.6554	3.421
Ratio $\frac{\sigma}{\sigma_1}$, of the densities of the powders	1	0.851	0.851	1	0.855
Ratios of the sides of the cube, $\epsilon = \frac{e'_s}{e_s} \cdot \frac{\sigma}{\sigma_1}$ . .	1	1.559	1.684	0.6554	2.925
Calculated side of cube, starting from 7mm. cube mm.	7	$\underbrace{10.913 \quad 11.788}_{\text{mean } 11.350}$		4.5878	20.475
Side of cube actually introduced	7	13	13	7	21

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* It might be supposed that, since e_s (or e'_s) is dependent on the path of the projectile, the grain dimensions in (10) must necessarily be dependent on it; but this is not so; because e_s (or e'_s) appears here as a condition of action.

Are the grain dimensions determined from this condition, the path of the projectile is to be so regulated that the condition of action is fulfilled.

No matter from what standpoint we regard the matter, we will always be forced to the conclusion that the length of tube depends on the grain dimensions and not the reverse.

cross-section energies and inversely proportional to the specific gravities (densities) of the powders.

Starting with the 7 mm. cubic powder used in the 9 cm. field gun M. 75, we wish to determine what should be the dimensions of the cubic powder in the gun M. 80, keeping the detonating action the same as in field gun.

The table on preceeding page contains all necessary data for this computation.

If in the guns considered, the density of the powder is the same as in the 7 mm. cubic powder, we obtain as the length of the cube's edge,

12 cm. siege gun M. 80.	12.817	mean 13.350 mm.
15 cm. siege gun M. 80.	13.853	
15 cm. sea-coast gun M. 80.	23.947 mm.	

In the 28 cm. sea-coast gun the projectile weighs 297 kg., the initial velocity is 560 m., the initial cross-section energy is 7.688 kgm., the ratio of the specific cross-section energies is 7.021.

In case we use powder of the same constitution and density as in the 7 mm. powder, the cubic grain would have to have a length of edge equal to 49.147 mm.; but if the density were as great as in the 21 mm. powder the edge of the cube would be 42.021 mm.

In order to avoid having grains of such large dimensions, a powder with small c_0, *i. e. brown* powder was introduced.

The calculations show quite a remarkable agreement with the results of experience, which goes to prove on the one hand, the great precision with which the Imperial and Royal Technical Military Committee determined the most appropriate powders, and on the other hand, the practical utility of the relations expressed in (10) and (10_1).

The discrepancy in case of the 18 cm. siege gun M. 80 may be explained by the fact that in the experiments the 7 mm. powder, which was ready at hand, was used and the results were considered satisfactory, or, that the passage from one set of grain dimensions to another, in the formulas given, only hold good in case of fire-arms of the *same sort.*

Theoretically, of course, this does not appear; but experience has given theory many a blow in the past.

However that may be, by the application of equations (10) or (10_1) we obtain a starting point for our investigations, and the latter are thereby confined to narrow limits.

It is also desirable to pass from one set of spaces occupied by the charge (loading densities) to another, which problem I have also solved, and expect to publish the results very soon.

Finally, be it remarked, the equations (10) and (10_1) apply with greater accuracy in the case of the *modern powders*, and this must be so, because they—as already explained—burn exactly according to the theoretical assumption, which, as is well known, is not the case with the old residue powders.

If, with a powder of the same constitution, the *density* is also the same, then $\sigma' = \sigma$, and equation (10) becomes

$$\varepsilon = \frac{e'_s}{e_s}; \qquad (10_2)$$

i. e., under the circumstances assumed, the homologous dimensions are proportional to the initial specific cross-section energies.

Equation (10) may be still further specialized, if we introduce the values of e_s and e'_s from equation (9); by which we obtain:

$$\varepsilon = \frac{c'_0}{c_0} \cdot \frac{\sigma}{\sigma_1} \cdot \frac{W'_s}{W_s} \cdot \frac{V_1^2}{V^2}, \qquad (11)$$

and if we substitute for W_s and W'_s the values

$$W_s = \frac{4W}{D^2\pi} \text{ and } W'_s = \frac{4W_1}{D_1^2\pi}.$$

in which D and D_1 are the respective calibers, we have:

$$\varepsilon = \frac{c'_0}{c_0} \cdot \frac{\sigma}{\sigma_1} \cdot \frac{W_1}{W} \cdot \frac{D^2}{D_1^2} \cdot \frac{V_1^2}{V^2}. \qquad (11_1)$$

If, *e. g.*, the powder is of similar constitution, and the densities and weights of projectiles are the same, we have from (11_1)

$$\varepsilon = \frac{D^2}{D_1^2} \cdot \frac{V_1^2}{V^2},$$

and from this, for equal initial velocities,

$$\varepsilon = \frac{D^2}{D_1^2}, \text{ etc.}$$

Finally, in equation (11), W_s and W'_s may be expressed in other forms, taking into account the influence of all elements coming into play in projectile construction.

If we assume the projectile to be changed to a *cylinder* of the same diameter and weight, the height of the cylinder will be approximately:

$$h - 0.4\,D,$$

in which h is the length of the projectile; and if s represent the average specific gravity of the projectile mass, then

$$W_s = (h - 0.4\,D)\,s = D\,(h' - 0.4)\,s,$$

in which h' is the length of the projectile; in the same way:

$$W'_s = D_1\,(h'_1 - 0.4) \cdot s_1,$$

from which relation equation (11) becomes:

$$\varepsilon = \frac{c'_0}{c_0} \cdot \frac{\sigma}{\sigma_1} \cdot \frac{D_1}{D} \cdot \frac{h'_1 - 0.4}{h' - 0.4} \cdot \frac{s_1}{s} \cdot \frac{V_1^2}{V^2}, \tag{12}$$

which admits of very extended specialization.

For $c'_0 = c_0$, $\sigma_1 = \sigma$ and $s_1 = s$ (assumptions which are very commonly true in practice), equation (12) becomes

$$\varepsilon = \frac{D_1}{D} \cdot \frac{h'_1 - 0.4}{h' - 0.4} \cdot \frac{V_1^2}{V^2}. \tag{12$_1$}$$

In case of *similar projectiles* $h'_1 = h'$, from which we have, from (12$_1$):

$$\varepsilon = \frac{D_1}{D} \cdot \frac{V_1^2}{V^2},$$

and in case of equal initial velocities,

$$\varepsilon = \frac{D}{D}, \text{ etc.}$$

We would also have arrived at the expression (10) by the requirement that *in both powders the velocity of emission at any moment* $\frac{da}{dt}$ *is constant.*

From equation (2) we obtain, for example:

$$\frac{da}{dt} = \frac{2}{a}\left(1 - 2\frac{\delta}{b}\right)\left(1 - 2\frac{\delta}{c}\right) \cdot \frac{d\delta}{dt} + \frac{2}{b}\left(1 - 2\frac{\delta}{a}\right)\left(1 - 2\frac{\delta}{c}\right) \cdot \frac{d\delta}{dt} + \frac{2}{c}\left(1 - 2\frac{\delta}{a}\right)\left(1 - 2\frac{\delta}{b}\right) \cdot \frac{d\delta}{dt},$$

and from equation (7)

$$\frac{d\delta}{dt} = \frac{c_0 \cdot p_m}{\sigma_0}.$$

Substituting these values for δ and $\frac{d\delta}{dt}$ in the equation for $\frac{da}{dt}$, we see at once that for the same velocities of emission equation (10) again results, as is, indeed, self evident.

In concluding my work I will add a few remarks on equation (7$_1$), *i. e.*,

$$\delta = \frac{c_0}{\sigma} \cdot \frac{e_s}{x_0} \cdot t. \tag{7$_1$}$$

If in this we substitute for δ the *smallest* semi-dimension of the grain, the t becomes the time of combustion of the charge, which we will designate by τ.

For example, if a be the smallest dimension in the parallelopipedon grain, we have from the above equation:

$$\tau = \frac{a}{2} \cdot \frac{\sigma}{c_0} \cdot \frac{x_0}{e_1}. \tag{13}$$

If we compare τ with the time of flight of the projectile in the bore, we can find out whether the charge is entirely consumed in the bore.

Unfortunately, I can give no examples as I do not know the value of c_0.

An approximate conception of the time of flight T of the shot in the bore may be obtained if we regard the movement as uniformly accelerated; then we have

$$T = \frac{2x_0}{V}. \tag{14}$$

we add a simple example.

	Field Gun	Siege Gun, M. 80.		
Caliber, cm.	9	12	15	18
Length of rifled bore (x_0) m.	1.460	2.135	2.330	1.195
Initial velocity	448	516	482	252

From these data equation (14) gives

$$T = 0.0066, \quad 0.0083, \quad 0.0097, \quad 0.0095.$$

We will use this time to determine limiting values for c_0.

If we assume that *the powder charge is entirely consumed at the instant the projectile leaves the bore,* we have from (7_1), if a represent the edge of the cube:

$$c_0 = \frac{a}{2} \cdot \frac{\sigma}{e_1} \cdot \frac{x_0}{T}. \tag{15}$$

If the charge is entirely consumed at an earlier period, a larger value for c_0 than that of (15) will result, and *vice versa* in the opposite case.

From (14) equation (15) may be transformed into:

$$c_0 = \frac{a}{2} \cdot \frac{\sigma}{e_1} \cdot \frac{V}{2}, \tag{15_1}$$

and from (9) into:

$$c_0 = \frac{g \cdot \pi}{8} \cdot a \cdot \frac{\sigma}{W} \cdot \frac{D^2}{V}. \tag{15_2}$$

By means of the data in the table on page 355, preserving the units there given, we obtain for the guns considered in the above example the following limiting values for c_0:

1.218 1.455 1.258 1.032.

If the powder charges in the four guns considered are completely consumed at *relatively equal* distances from the muzzle, very nearly equal limiting values for c_0 would result.

—*Mittheilungen über Gegenstände des Artillerie und Genie Wessens*, No. 2, 1897.

[Translated by Lieutenant J. P. Wisser, 1st Artillery.]

ERRATA.

Page 349, line 2, should read:

$$a = 1 - \left(1 - 2\frac{\delta}{a}\right)^3. \tag{3}$$

Page 350, table, column β_2, second line, should read:

$$-4\left(\frac{1}{ab} + \frac{1}{ac} + \frac{1}{bc}\right)$$

THE RESISTANCE OF AIR TO THE MOTION OF PROJECTILES.*

Translated from the Italian in the Rivista di Artiglieria e Genio, March, 1896.

NUMBER III, SECTION I.

In our second article it was pointed out that the proposed hyperbola gave for low velocities resistances a little too great, i. e., greater than those given by the formulas in actual use. Although we are unacquainted with any experiments for the direct determination of the resistance corresponding to velocities below 140 m., it is nevertheless true that the formulas now in use give ranges and angles which agree sufficiently well with those obtained in practice. Now since the resistance given by these formulas is, for low velocities, notably lower than that given by the hyperbola, we must conclude that this last requires a correction.

This correction as we said before, is easily introduced by means of an additional term which vanishes when the velocity exceeds a certain limit. By taking account of this term, the curve of resistance becomes a curve of a higher order, which, for velocities above the limit referred to, approaches an hyperbola just as the hyperbola for the highest velocities approaches a right line. The retardation, therefore, whatever be the velocity, is always given by one and the same equation, viz :

$$(S).\quad r=\frac{\delta i}{C}F(v)=\frac{\delta i}{C}\left[0.2002\,v-48.05+\sqrt{(0.1648\,v-47.05)^2+9.6}\right.$$
$$\left.+\frac{0.0442\,v\,(v-300)}{37^{1}+\left(\frac{v}{200}\right)^{10}}.\right]$$

The hyperbola which forms the basis of this equation and which results by neglecting the last term of the second member, is a little different from that proposed in our first article. Since that hyperbola does not represent very well the resistance due to low velocities, we have modified it slightly and in such a manner that the curve (S) may represent with the greatest possible exactness the results of all the experiments, not only as regards the lowest, but also the medium as well as the highest velocities.

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* See Journal for May-June and September-October, 1896.

We give at the end of the present article a table of values of $F(v)$ and of $\frac{F(v)}{v^2} = K(v)$, from $v = o$ to $v = 1200$ with intervals of one meter. The values of $F(v)$ were calculated directly by formula (S) at intervals of five meters up to $v = 400$; at intervals of 10 meters up fo $v = 500$, and at intervals of 50 meters up to $v = 1200$ meters. The other values were interpolated.

The curve (S), Fig. 1, has the following characteristics:

1. It has the same asymptote as the first hyperbola, viz:

$$r = \frac{\delta i}{C}(0.365\,v - 96).$$

2. It is tangent to the axis of velocities.

3. The retardation increases as the square of the velocity from $v = o$ to $v = 240$ about.

4. It has two points of inflection, one at $v = 340$ about (the velocity of sound), and the other between $v = 420$ and $v = 430$.*

The curve $K(v)$, Fig. 2, has a direction sensibly horizontal up to $v = 240$ about; then it rises rapidly and reaches a maximum at $v = 520$. It has two points of inflection; one at $v = 310$, and one at $v = 780$ about.

In order to form an estimate of our accuracy, the differences between the values given by the curve (S) and those given by the Russian and English experiments (R and E), by the Dutch experiments (D), and by the Meppen firings (M), may be seen in the table on following page.

As to the Meppen firings, the values of $\frac{Cr}{\delta i}$ have been deduced by means of the expression

$$\frac{a}{i}(v - 263),$$

(making use of the two tables given in our second article), placing for v the measured velocity, for a the values given in the tables referred to, and making $i = 0.896$.

As to the Dutch experiments, curve (S) reproduces them, after making $i = 0.896$, with a mean quadratic error of 1.34; while

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* These two points of inflection are not apparent in Fig. 1 on account of the smallness of the scale, but they are clearly brought out by the change of sign in the second differences, thus:

v	310	320	330	340	350	360	370
$F(v)$	18.73	22.32	26.00	29.72	33.44	37.12	40.77
$\Delta F(v)$		3.59	3.68	3.72	3.72	3.68	3.65
$\Delta_2 F(v)$		+0.09	+0.04	0	−0.04	0.03	

and

v	400	410	428	430	440	450	460
$F(v)$	51.533	53.078	58.618	62.154	65.694	69.240	72.722
$\Delta F(v)$		3.545	3.539	3.537	3.540	3.546.	3.552
$\Delta_2 F(v)$		−0.006	−0.002	+0.003	+0.006	+0.006	

Experiments.	v	$\frac{Cr}{\delta i} = F(v)$.		Difference.	Experiments.	v	$\frac{Cr}{\delta i} = F(v)$.		Difference.
		Experi-ments.	Curve (S).				Experi-ments.	Curve (S).	
		$i = 1$					$i = 1$		
R	172	3.4	3.6	—0.2	E	355	35.3	35.3	0.0
R	207	4.5	5.3	−0.8	E	358	37.7	36.4	+0.7
R	239	6.5	7.2	—0.7	R	360	38.4	37.1	+1.3
R	247	8.0	7.7	+0.3	E	360	39.2	37.1	+2.1
R	266	8.7	9.3	—0.6	R	401	55.6	51.9	+3.7
R	282	10.2	11.3	—1.1	R	409	55.4	54.7	+0.7
E	287	11.7	12.1	—0.4	E	419	58.5	58.4	+0.1
E	291	16.1	13.0	+3.1	E	420	58.0	58.6	—0.6
E	300	15.9	15.4	+0.5	E	460	73.2	72.8	+0.4
E	302	15.3	16.1	—0.8	E	508	87.5	90.0	—2.5
R	304	15.7	16.7	—1.0	E	572	89.4	91.4	—2.0
R	307	11.2	17.7	—6.5			$i = 0.896$		
E	316	23.5	20.8	+2.7					
R	317	12.7	21.2	—8.5	D	150	3.1	2.7	+0.4
R	319	13.6	21.9	—8.3	D	200	4.5	4.9	−0.4
E	320	21.8	22.3	—0.5	D	250	9.9	8.0	+1.9
R	320	23.6	22.3	+1.3	D	300	15.3	15.4	—0.1
E	322	21.6	23.0	—1.4	D	350	33.3	33.4	—0.1
R	329	28.1	25.6	+2.5	D	400	53.0	51.5	+1.5
E	332	27.8	26.7	+1.1	D	450	70.3	69.2	+1.1
E	334	28.6	27.5	+1.1	D	500	86.1	87.1	−1.0
R	337	29.9	28.6	+1.3	D	550	101.6	105.1	−3.5
E	340	29.7	29.7	0.0	D	600	125.7	123.2	+2.5
E	345	32 5	31.6	+0.9	D	650	138.2	141.4	−3.2
		$i = 0.896$					$i = 0.896$		
M	368	38	40	— 2	M	759	185	181	+ 4
M	438	60	65	— 5	M	780	188	189	— 1
M	438	61	65	— 4	M	783	195	190	+ 5
M	488	79	83	— 3	M	783	194	190	+ 4
M	534	101	100	+ 1	M	807	203	199	+ 4
M	581	109	115	— 6	M	808	204	199	+ 5
M	581	116	115	+ 1	M	819	190	203	—13
M	582	114	117	— 3	M	835	201	209	— 8
M	583	119	117	+ 2	M	837	204	210	— 6
M	607	140	126	+14	M	839	200	210	—10
M	620	135	130	+ 5	M	840	231	211	+20
M	664	143	146	— 3	M	853	210	215	— 5
M	672	152	149	+ 3	M	871	227	221	+ 6
M	672	148	149	— 1	M	877	230	224	+ 6
M	681	176	153	+ 3	M	900	219	232	—13
M	717	172	166	— 6	M	910	263	236	+27
M	717	169	166	— 3					

the discontinuous curve given by the five monomial equations of Hojel reproduces the same experiments with a mean quadratic error of 1.51.*

It must also be borne in mind that the error 1.34 which corresponds to $i = 0.896$, is not a minimum. The value of i which gives the minimum error is 0.891; and the mean quadratic error then falls to 1.31.

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* In our first article we stated that the mean quadratic error of Hojel's monomial equations was 1.432. Performing the calculations again, we find it to be 1.513.

The property of the curve (S), by virtue of which it gives resistances proportional to the square of the velocity up to 240 *m.* is, as is well known, of advantage in certain special problems relating to curved and indirect fire. It may be assumed that for all velocities below 240 *m.*,

$$r = \frac{\delta i}{C} \, 0.000123 \, v^2,$$

which becomes, when $i = 0.896$,

$$r = \frac{\delta}{C} \, 0.000110 \, v^2,$$

a formula almost identical with that derived by Mayevski from the Meppen firings, viz:

$$r = \frac{\delta}{C} \, 0.000108 \, v^2,$$

the difference between the two being, as we shall now show, in favor of our own formula, *i. e.*, curve (S).

The Meppen firings which served as a basis for Mayevski's formulas are reduced to two single shots which we here quote from the work of that author, already referred to in our first article.*

a	p	Weight of a cubic meter of air.	Distance x between v' and v''.	Measured horizontal velocity.		Calculated horizontal velocity.	
				v'	v''	v''	$\Delta v''$
m	*kg*	*kg*	*m*	*m*	*m*	*m*	*m*
0.1070	12.5	1.218	777.5	205.1	188.2	188.2	0.0
0.1524	31.5	1.206	966.5	203.0	188.0	188.0	0.0

The last column of this table would show a perfect agreement between Mayevski's formula and the two Meppen firings, were it not for the fact that this perfect agreement arises from some inexactness in the ballistic tables of Colonel Langeskiold, from which the velocities v'' were derived.

Let us suppose the retardation to be represented by

$$r = \frac{\delta}{C} \, k v^2,$$

and then calculate k by means of the two firings referred to.

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* *Ueber die Lösung der Problemen.*

Neglecting the curvature of the trajectory, which is in fact insignificant, we have

$$\frac{v\,dv}{dx} = -\frac{\delta}{C}\,kv^2,$$

$$\frac{\delta k x}{C} = -\int_{v'}^{v''} \frac{dv}{v} = \text{Nap. log}\,\frac{v'}{v''},$$

and therefore

$$k = \frac{C}{\delta x}\Big[\ 0.3622157\ \Big]\log\frac{v'}{v''}.$$

Now in the two firings we have

$$\log\frac{C}{\delta} = 0.0338424, \qquad \log\frac{C}{\delta} = 0.1323406.$$

Placing these two values successively in the preceeding formula, with the corresponding values of v', v'', and x, we find,

$$k = 0.00011957, \qquad k = 0.00010772.$$

The mean is

$$k = 0.00011364,$$

and is nearer to 0.000110 than to 0.000108.

Observations. With equations of the form

$$(S') \;.\;.\;.\;.\; r = \frac{\delta i}{C}\left[av - \beta + \sqrt{a^2v^2 - 2abv + c^2} + \frac{\Phi(v)}{\Psi(v)}\right]$$

(where $\Phi(v)$ and $\Psi(v)$ are two integral algebraic functions of v, and the second of a higher order than the first), asymptotic curves can be obtained which reproduce even more sharply than curve (S) certain sinuosities which appear in some of the discontinuous curves with which, up to the present time, the resistance of the air has been represented. But it should be borne in mind that these sinuosities, besides being very slight, depend more upon the formulas adopted than upon the immediate results of experiment; and it is to these alone, that he who investigates the laws of resistance must devote his attention.

To us it seems that the curve (S), which gives a resistance proportional to the square of the velocity up to 240 *m.* about; which reproduces the experiments of Hojel (which are the most accurate) with a greater exactness than the discontinuous curve proposed by Hojel himself; and which for the highest velocities passes symmetrically among the experimental points; to us it seems that such a curve must fully satisfy the artillerist, at least until new instruments, whose precision is well established to be superior to that of the electric chronograph now in use, shall modify sensibly the results obtained by the experiments of the last thirty years.*

SECTION TWO.

At the beginning of our first article we pointed out the fact that the hyperbola there considered could be divided into two other twin hyperbolas which give the resistance almost as well as the original curve; one from the lowest velocities up to about 280 *m.* and the other from that point upward; also that the twin hyperbolas are tangent to the present curve and osculatory to each other at the same point.

These properties pertain also to the curve (S), arising from the development into a series, of the radical which appears in the second member of $F(v)$.

The division now falls however at the velocity 291.57, because the radical of curve (S) is a little different from that of hyperbola (1). The two curves are given by the following equations in round numbers,

$$(S)_1 \quad F(v) = 0.0350\,v - 0.18 + \frac{64}{311 - v} + \frac{0.0442\,v\,(v - 300)}{371 + \left(\frac{v}{200}\right)^{10}},$$

$(v < 292)$.

$$(S)_2 \quad F(v) = 0.365\,v - 96 + \frac{53}{v - 273} + \frac{0.0442\,v\,(v - 300)}{371 + \left(\frac{v}{200}\right)^{10}},$$

$(v > 292)$.

The table below gives a comparison of the results obtained by formulas (S), $(S)_1$, and $(S)_2$.

v	Formulas.		v	Formulas.		v	Formulas.		v	Formulas.	
	(S)	$(S)_1$		(S)	$S)_2$		(S)	$(S)_2$		(S)	$(S)_2$
50	0.30	0.33	300	15 45	15.46	550	105.10	105.18	800	196.07	196.12
100	1.21	1.24	350	33.44	33.64	600	123.24	123.30	850	214.31	214.35
150	2.73	2.79	400	51.53	51.68	650	141.41	141.47	900	232.55	232.59
200	4.92	5.02	450	69.24	69.36	700	159.62	159.66	950	250.80	250.83
250	7.97	8.16	500	87.08	87.18	750	177.84	177.89	1000	269.04	269.08

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* De La Llave has recently (*Memorial de Artilleria* for January, 1896), established eight monomial formulas by which he represents the resistance of the air up to 1500 *m*, based upon Hojel's experiments and the Meppen firings. They reproduce the Dutch experiments with a mean quadratic error 1.45; an error less than that given by Hojel's formulas, viz: 1.51, but larger than that given by curve (S), viz: 1.34.

To show how $(S)_1$ and $(S)_2$ are derived from S, let us place

$$R = \sqrt{(0.1648\, v - 47.95)^2 + 9.6} = \sqrt{a^2v^2 - 2\, abv + c^2},$$

where

$$a = 0.1648, \qquad b = 47.95, \qquad c = 48.05.$$

Placing also

$$v_0 = \frac{c}{a} = 291.5655 \ldots,$$

$$\cos a = \frac{c - \sqrt{c^2 - b^2}}{b} = \frac{48.05 - \sqrt{9.6}}{47.95},$$

we have

$$a = 20^\circ\ 22'\ 10'',$$

$$c = a\, v_0,\ a\, b = \frac{2\, a^2\, v_0 \cos a}{1 + \cos^2 a},$$

$$R = a\sqrt{v^2 + v_0^2 - \frac{4\, v\, v_0 \cos a}{1 + \cos^2 a}}$$

$$= \frac{a\sqrt{(v^2 + v_0^2)(1 + \cos^2 a) - 4\, v_0\, v \cos a}}{\sqrt{1 + \cos^2 a}}.$$

Now by a easy reduction we find,

$$\frac{a}{\sqrt{1 + \cos^2 a}} \sqrt{\frac{ab}{2\, v_0 \cos a}}$$

$$(v^2 + v_0^2)(1 + \cos^2 a) - 4\, v\, v_0 \cos a = 2\, (v_0 - v \cos a)^2 - (v_0^2 - v^2) \sin^2 a$$
$$= 2\, (v - v_0 \cos a)^2 - (v^2 - v_0^2) \sin^2 a,$$

from which we may write indifferently,

$$R = \sqrt{\frac{ab}{v_0 \cos a}}\, (v_0 - v \cos a) \left[1 - \frac{\sin^2 a}{2} \frac{v_0^2 - v^2}{(v_0 - v \cos a)^2}\right]^{\frac{1}{2}}$$

or

$$R = \sqrt{\frac{ab}{v_0 \cos a}}\, (v - v_0 \cos a \left[1 - \frac{\sin^2 a}{2} \frac{v^2 - v_0}{(v - v_0 \cos a}\right]^{\frac{1}{2}}.$$

If now we use the first expression when $v < v_0$, and the second when $v > v_0$, the quantities in the brackets may be developed into converging series. Stopping the development with the second term we have

$$R = \sqrt{\frac{ab}{v_0 \cos a}} \left[(v_0 - v \cos a) - \frac{\sin^2 a}{4} \frac{v_0^2 - v^2}{v_0 - v \cos a}\right], (v < v_0)$$

$$R = \sqrt{\frac{ab}{v_0 \cos a}} \left[(v - v_0 \cos a) - \frac{\sin^2 a}{4} \frac{v^2 - v_0^2}{v - v_0 \cos a}\right], (v > v_0).$$

These expressions are then easily reduced to

$$R = \sqrt{\frac{ab}{v_0 \cos a}} \left[v_0 \left(1 - \frac{\tan^2 a}{4} \right) - v \cos a \left(1 + \frac{\tan^2 a}{4} \right) \right.$$
$$\left. + \frac{\sin^4 a}{4 \cos^2 a} \cdot \frac{v_0^2}{v_0 \sec a - v} \right], (v < v_0)$$

$$R = \sqrt{\frac{ab}{v_0 \cos a}} \left[v \left(1 - \frac{\sin^2 a}{4} \right) - v_0 \cos a \left(1 + \frac{\sin^2 a}{4} \right) \right.$$
$$\left. + \frac{\sin^4 a}{4} \cdot \frac{v_0^2}{v - v_0 \cos a} \right], (v > v_0),$$

by noting that

$$\frac{v_0^2 - v^2}{v_0 - v \cos a} = \frac{1}{\cos a} \cdot \frac{v^2 - v_0^2}{v - v_0 \sec a}$$
$$= \frac{1}{\cos a} \frac{(v^2 - v_0^2 \sec^2 a + v_0^2 \tan^2 a)}{v - v_0 \sec a} = \frac{v + v_0 \sec a}{\cos a}$$
$$+ \frac{v_0^2 \tan^2 a \sec a}{v - v_0 \sec a},$$

and that

$$\frac{v^2 - v_0^2}{v - v_0 \cos a} = \frac{v^2 - v_0^2 \cos^2 a - v_0^2 \sin^2 a}{v - v_0 \cos a}$$
$$= v + v_0 \cos a - \frac{v_0^2 \sin^2 a}{v - v_0 \cos a}.$$

Restoring the numbers, we have,

$$R = 47.866 - 0.16489\, v + \frac{64.379}{311.014 - v} \quad (v < 291.5655)$$

$$R = 0.16488\, v - 47.8826 + \frac{53.041}{v - 273.333} \quad (c > 291.5655).$$

Substituting finally in (S) and neglecting superfluous decimal places, we obtain $(S)_1$ and $(S)_2$.

These expressions, as also that for (S), introduced into the formulas which define the ballistic functions D, T, J, and β, give rise to integrations which are somewhat complicated, but yet performed with elementary functions. We may however avoid these complications by resorting to the well known process of *quadratures*.

We shall publish shortly a new table of the four ballistic functions,

$$D,\ A,\ J,\ T,$$

based upon formula (S), as also a table of the fifth function β, based upon the same formula.

Naples, March 29, 1896. F. SIACCI.

[Translated by Lieutenant F. S. HARLOW, 1st ARTILLERY.]

Resistance of the Air.

$$r = \frac{\delta i}{C} F(v) =$$

$$\frac{\delta i}{C}\left[0.2002\,v - 48.05 + \sqrt{(0.1648\,v - 47.95)^2 + 9.6} + \frac{0.0442\,v\,(v - 300)}{371 + \left(\frac{v}{200}\right)^{10}}\right].$$

$$K(v) = \frac{F(v)}{v^2}.$$

v	$F(v)$		$10^6 K(v)$	v	$F(v)$		$10^6 K(v)$	v	$F(v)$		$10^6 K(v)$
0	0.00000	12	120	50	0.301	12	121	100	1.210	24	121
1	0.00012	36	“	1	0.313	12	“	1	1.234	24	“
2	0.00048	60	“	2	0.325	13	“	2	1.258	25	“
3	0.00108	84	“	3	0.338	13	“	3	1.283	25	“
4	0.00192	108	“	4	0.351	14	“	4	1.308	26	“
5	0.00300	132	“	5	0.365	13	“	5	1.334	25	“
6	0.00432	156	“	6	0.378	14	“	6	1.359	26	“
7	0.00588	180	“	7	0.391	14	“	7	1.385	26	“
8	0.00768	204	“	8	0.405	14	“	8	1.411	27	“
9	0.00972	23	“	9	0.449	15	“	9	1.438	27	“
10	0.0120	25	120	60	0.434	15	121	110	1.465	27	121
1	0.0145	28	“	1	0 449	14	“	1	1.482	27	“
2	0.0173	30	“	2	0.463	16	“	2	1.519	28	“
3	0.0203	32	“	3	0.479	15	“	3	1.547	28	“
4	0.0235	35	“	4	0.494	16	“	4	1.575	27	“
5	0.0270	38	“	5	0.510	16	“	5	1.602	29	“
6	0.0308	40	“	6	0.526	16	“	6	1.631	28	“
7	0.0348	42	“	7	0.542	16	“	7	1.659	28	“
8	0.0390	45	“	8	0.558	16	“	8	1.687	29	“
9	0.0435	47	“	9	0.574	17	“	9	1.716	29	“
20	0.0482	49	120	70	0.591	18	121	120	1.745	29	121
1	0.0531	51	“	1	0.609	17	“	1	1.774	30	“
2	0.0582	55	“	2	0.626	17	“	2	1.804	29	“
3	0.0637	57	“	3	0.643	18	“	3	1.833	30	“
4	0.0694	59	“	4	0.661	19	“	4	1.863	31	“
5	0.0753	61	“	5	0.680	18	“	5	1.894	31	“
6	0.0814	64	“	6	0.698	18	“	6	1.925	31	“
7	0.0878	66	“	7	0.716	17	“	7	1.956	31	“
8	0.0944	69	“	8	0.735	19	“	8	1.987	32	“
9	0.1013	72	121	9	0.754	19	“	9	2.019	31	“
30	0.1085	73	121	80	0.773	20	121	130	2.050	32	121
1	0.1158	76	“	1	0.793	20	“	1	2.082	32	“
2	0.1234	78	“	2	0.813	20	“	2	2.114	32	“
3	0.1312	81	“	3	0.833	21	“	3	2.146	33	“
4	0.1393	83	“	4	0.854	20	“	4	2.179	32	“
5	0.1476	85	“	5	0.874	21	“	5	2.211	33	“
6	0.1561	88	“	6	0.895	21	“	6	2.244	34	“
7	0.1649	91	“	7	0.916	21	“	7	2.278	34	“
8	0.1740	93	“	8	0.937	21	“	8	2.312	33	“
9	0.1833	96	“	9	0.948	21	“	9	2.345	34	“
40	0.1929	98	121	90	0.979	22	121	140	2.379	34	121
1	0.2027	100	“	1	1.001	23	“	1	2.443	35	“
2	0.2127	102	“	2	1.024	23	“	2	2.448	35	“
3	0.2229	104	“	3	1.047	23	“	3	2.483	35	“
4	0.2333	107	“	4	1.070	22	“	4	2.518	35	“
5	0.2441	110	“	5	1.092	23	“	5	2.553	36	“
6	0.2551	112	“	6	1.115	23	“	6	2.589	37	“
7	0.2663	114	“	7	1.138	24	“	7	2.626	36	“
8	0.2777	117	“	8	1.162	24	“	8	2.662	36	“
9	0.2894	120	“	9	1.186	24	“	9	2.698	37	“
50	0.3014		121	100	1.210		121	150	2.735		121

v	$F(v)$		$10^6 K(v)$	v	$F(v)$		$10^6 K(v)$	v	$F(v)$		$10^6 K(v)$
150	2.735		121	200	4.920		123	250	7.97		128
1	2.772	37	"	1	4.971	51	"	1	8.05	8	"
2	2.809	37	"	2	5.022	51	"	2	8.12	7	"
3	2.846	37	"	3	5.073	51	"	3	8.20	8	"
4	2.883	37	"	4	5.125	52	"	4	8.28	8	"
5	2.921	38	122	5	5.177	52	"	5	8.36	8	"
6	2.959	38	"	6	5.230	53	"	6	8.44	8	129
7	2.998	39	"	7	5.284	54	"	7	8.53	9	"
8	3.037	39	"	8	5.338	54	"	8	8.61	8	"
9	3.076	39	"	9	5.392	54	"	9	8.69	8	"
160	3.116	40	122	210	5.447	55	123	260	8.78	9	130
1	3.155	39	"	1	5.501	54	"	1	8.86	8	"
2	3.195	40	"	2	5.556	55	124	2	8.95	9	"
3	3.235	40	"	3	5.611	55	"	3	9.04	9	131
4	3.275	40	"	4	5.666	55	"	4	9.13	9	131
5	3.316	41	"	5	5.722	56	"	5	9.23	10	131
6	3.357	41	"	6	5.778	55	"	6	9.33	10	132
7	3.399	42	"	7	5.835	57	"	7	9.43	10	132
8	3.440	41	"	8	5.892	57	"	8	9.53	10	133
9	3.482	42	"	9	5.950	58	"	9	9.63	10	133
170	3.524	42	122	220	6.009	59	124	270	9.73	10	133
1	3.567	43	"	1	6.067	58	"	1	9.84	11	134
2	3.610	43	"	2	6.126	59	"	2	9.95	11	135
3	3.653	43	"	3	6.184	58	"	3	10.06	11	135
4	3.696	43	"	4	6.244	60	"	4	10.18	12	136
5	3.738	42	"	5	6.303	59	"	5	10.30	12	136
6	3.782	44	"	6	6.363	60	125	6	10.42	12	137
7	3.825	43	"	7	6.424	61	"	7	10.55	13	137
8	3.870	45	"	8	6.486	62	"	8	10.68	13	138
9	3.914	44	"	9	6.548	62	"	9	10.82	14	139
180	3.959	45	122	230	6.612	64	125	280	10.97	15	140
1	4.004	45	"	1	6.675	63	"	1	11.12	15	141
2	4.050	46	"	2	6.739	64	"	2	11.28	16	142
5	4.097	47	"	3	6.804	65	"	3	11.44	16	143
4	4.143	46	"	4	6.869	65	"	4	11.61	17	144
5	4.189	46	"	5	6.935	66	126	5	11.78	17	145
6	4.236	47	"	6	7.000	65	"	6	11.96	18	146
7	4.283	47	"	7	7.066	66	"	7	12.15	19	148
8	4.331	48	"	8	7.131	65	"	8	12.35	20	149
9	4.378	47	"	9	7.197	66	"	9	12.57	22	151
190	4.426	48	123	240	7.262	66	126	290	12.80	23	152
1	4.474	48	"	1	7.329	67	"	1	13.02	22	154
2	4.523	49	"	2	7.397	68	"	2	13.25	23	155
3	4.571	48	"	3	7.465	68	127	3	13.49	24	157
4	4.620	49	"	4	7.533	68	"	4	13.74	25	159
5	4.669	49	"	5	7.611	68	"	5	14.00	26	161
6	4.719	50	"	6	7.680	69	"	6	14.27	27	163
7	4.769	50	"	7	7.751	71	"	7	14.55	28	165
8	4.819	50	"	8	7.824	73	"	8	14.84	29	167
9	4.870	51	"	9	7.898	74	"	9	15.14	30	169
200	4.920	50	"	250	7.974	76	128	300	15.45	31	172

v	$F(v)$		10^6 $K(v)$	v	$F(v)$		10^6 $K(v)$	v	$F(v)$		10^6 $K(v)$
300	15.45		172	350	33.44		273	400	51.53		322
1	15.06	31	174	1	33.81	37	274	1	51.88	34	323
2	16.07	31	176	2	34.18	37	276	2	52.24	36	323
3	16.39	32	178	3	34.55	37	277	3	52.59	35	324
4	16.71	32	181	4	34.92	37	278	4	52.95	36	324
5	17.03	32	183	5	35.29	37	280	5	53.40	35	325
6	17.36	33	185	6	35.65	38	281	6	53.76	36	325
7	17.70	34	188	7	36.02	37	282	7	54.11	35	326
8	18.04	34	190	8	36.38	36	284	8	54.37	36	326
9	18.38	34	192	9	36.75	37	285	9	54.72	36	327
310	18.73	35	195	360	37.12	37	286	410	55.08	36	328
1	19.08	35	197	1	37.49	37	288	1	55.43	35	328
2	19.43	35	199	2	37.85	37	289	2	55.89	36	328
3	19.78	35	202	3	38.22	37	290	3	56.24	35	329
4	20.13	35	204	4	38.59	37	291	4	56.60	36	329
5	20 49	36	206	5	38.95	38	292	5	56.95	35	330
6	20.85	36	209	6	39.32	37	293	6	57.30	35	331
7	21.21	36	211	7	39.68	36	295	7	57.66	36	331
8	21.58	37	213	8	40.04	36	296	8	58.01	35	331
9	21.95	37	215	9	40.40	36	297	9	58.36	35	332
320	22.32	37	218	370	40.77	37	298	420	58.62	36	332
1	22.68	36	220	1	41.13	36	299	1	58.91	35	333
2	23.05	37	222	2	41.50	37	300	2	59.32	36	333
3	23.41	36	224	3	41.86	36	301	3	59.68	36	333
4	23.77	36	226	4	42.22	36	302	4	60.03	35	334
5	24.14	37	228	5	42.59	37	303	5	60.38	35	334
6	24.51	38	230	6	42.95	36	304	6	60.74	36	335
7	24.88	37	233	7	43.31	36	305	7	61.09	35	335
8	25.25	37	235	8	43.67	36	306	8	61.44	35	335
9	25.62	37	237	9	44.03	36	306	9	61.80	36	336
330	26.00	38	239	380	44.39	36	307	430	62.15	35	336
1	26.37	37	241	1	44.75	36	308	1	62.51	36	336
2	26.74	37	243	2	45.15	36	309	2	62.86	35	337
3	27.12	35	244	3	45.47	36	310	3	63.21	35	337
4	27.49	37	246	4	45.83	36	311	4	63.57	36	337
5	27.86	37	248	5	46.18	35	312	5	63.92	35	338
6	28.23	37	250	6	46.54	36	312	6	64.27	35	338
7	28.60	37	252	7	46.90	36	313	7	64.63	36	338
8	28.98	38	253	8	47.26	36	314	8	64.98	35	339
9	29.35	37	255	9	47.62	36	315	9	65.34	36	339
340	29.72	37	257	390	47.97	35	315	440	65.69	35	339
1	30.10	38	259	1	48.33	36	316	1	66.05	36	340
2	30.47	37	260	2	48.68	36	317	2	66.40	35	340
3	30.84	37	262	3	49.04	36	318	3	66.76	36	340
4	31.21	37	264	4	49.40	36	318	4	67.11	35	340
5	31.58	37	265	5	49.75	35	319	5	67.47	36	341
6	31.95	37	267	6	50.11	36	320	6	67.82	35	341
7	32.32	37	268	7	50.46	35	320	7	68.18	36	341
8	32.70	38	270	8	50.82	36	321	8	68.54	36	341
9	33.07	37	271	9	51.18	36	322	9	68.89	35	342
350	33.44	37	273	400	51.53	37	323	450	69.24	35	342

v	$F(v)$		10^6 $K(v)$	v	$F(v)$		10^6 $K(v)$	v	$F(v)$		10^6 $K(v)$
450	69.24		342	500	87.08		348	550	105.10		347
1	69.59	35	342	1	87.45	37	348	1	105.46	36	347
2	69.95	36	342	2	87.81	36	348	2	105.82	36	347
3	70.30	35	343	3	88.17	36	348	4	106.18	36	347
4	70.66	36	343	4	88.53	36	348	4	106.55	37	347
5	71.01	35	343	5	88.89	36	348	5	106.91	36	347
6	71.37	36	343	6	89.25	36	348	6	107.27	36	347
7	71.72	36	343	7	89.61	36	348	7	107.63	36	347
8	72.08	36	344	8	89.97	36	348	8	107.99	36	347
9	72.43	35	344	9	90.33	36	348	9	108.36	37	347
460	72.79	36	344	510	90.68	35	348	560	108.72	36	347
1	73.14	35	344	1	91.04	36	349	1	109.08	36	347
2	73.50	36	344	2	91.40	36	349	2	109.45	37	346
3	73.85	35	345	3	91.76	36	349	3	109.81	36	546
4	74.21	36	345	4	92.12	36	349	4	110.17	36	346
5	74.57	36	345	5	92.48	36	349	5	110.53	36	346
6	74.92	35	345	6	92.84	36	349	6	110.90	37	346
7	75.28	36	345	7	93.20	36	349	7	111.26	36	346
8	75.64	36	346	8	93.56	36	349	8	111.62	36	346
9	76.00	36	346	9	94.92	36	349	9	111.99	37	346
470	76.35	35	346	520	94.28	36	349	570	112.35	36	346
1	76.71	36	346	1	94.64	36	349	1	112.71	36	346
2	77.06	35	346	2	95.00	36	349	2	113.07	36	346
3	77.41	35	346	3	95.36	36	349	3	113.44	37	345
4	77.77	36	347	4	95.72	36	349	4	113.80	36	345
5	78.12	35	347	5	96.08	36	349	5	114.16	36	345
6	78.48	36	347	6	96.44	36	348	6	114.53	37	345
7	78.84	36	347	7	96.80	36	348	7	114.89	36	345
8	79.20	36	347	8	97.16	36	348	8	115.25	36	345
9	79.56	36	347	9	97.52	36	348	9	115.62	37	345
480	79.92	36	347	530	97.88	36	348	580	115.98	36	345
1	79.28	36	347	1	98.24	36	348	1	116.34	36	345
2	79.64	36	347	2	98.60	36	348	2	116.70	36	345
3	80.00	36	347	3	98.96	36	348	3	117.07	37	344
4	80.35	35	347	4	99.32	36	348	4	117.43	36	344
5	80.71	36	348	5	99.68	36	348	5	117.79	36	344
6	81.07	36	348	6	100.04	36	348	6	118.16	37	344
7	81.43	36	348	7	100.40	36	348	7	118.52	36	344
8	81.79	36	348	8	100.76	36	348	8	118.88	36	344
9	83.15	36	348	9	101.12	36	348	9	119.25	37	344
490	83.50	35	348	540	101.49	37	348	590	119.61	36	344
1	83.86	36	348	1	101.85	36	348	1	119.97	36	343
2	84.22	36	348	2	102.21	36	348	2	120.33	36	343
3	84.58	36	348	3	102.57	35	348	3	120.70	37	343
4	84.94	36	348	4	102.93	36	348	4	121.06	36	343
5	85.30	36	348	5	103.29	36	348	5	121.42	36	343
6	85.66	36	348	6	103.65	36	348	6	121.79	37	343
7	86.01	35	348	7	104.01	36	348	7	122.15	36	343
8	86.37	36	348	8	104.37	36	347	8	122.51	36	343
9	86.72	36	348	9	104.73	36	347	9	122.87	36	342
500	87.08	36	348	550	105.10	37	347	600	123.24	37	342

v	$F(v)$		$10^6 K(v)$	v	$F(v)$		$10^6 K(v)$	v	$F(v)$		$10^6 K(v)$
600	123.24		342	650	141.41		335	700	159.62		326
1	123.60	36	342	1	141.78	37	335	1	159.98	36	326
2	123.96	36	342	2	142.14	36	334	2	160.34	36	325
3	124.33	37	342	3	142.50	36	334	3	160.71	37	325
4	124.69	36	342	4	142.87	37	334	4	161.07	36	325
5	125.05	36	342	5	143.23	36	334	5	161.43	36	315
6	125.42	36	341	6	143.60	37	334	6	161.80	37	324
7	125.78	36	341	7	143.96	36	333	7	162.16	36	324
8	126.14	36	341	8	144.32	36	333	8	162.53	37	324
9	126.50	36	341	9	144.69	37	333	9	162.90	37	324
610	126.87	37	341	660	145.05	36	333	710	163.26	36	324
1	127.23	36	341	1	145.41	36	333	1	163.63	37	323
2	127.59	36	341	2	145.78	37	333	2	163.99	36	323
3	127.96	37	340	3	146.14	36	332	3	164.35	36	323
4	128.32	36	340	4	146.50	36	332	4	164.72	37	323
5	128.69	37	340	5	146.87	37	332	5	165.08	36	323
6	129.05	36	340	6	147.23	36	332	6	165.44	36	323
7	129.42	37	340	7	147.60	37	332	7	165.81	37	322
8	129.78	36	340	8	147.97	37	332	8	166.17	36	322
9	130.14	36	340	9	148.33	36	331	9	166.54	37	322
620	130.50	36	339	670	148.69	36	331	720	166.90	36	322
1	130.86	36	339	1	149.06	37	331	1	167.26	36	322
2	131.23	37	339	2	149.42	36	331	2	167.63	37	322
3	131.59	36	339	3	149.78	36	331	3	167.99	36	321
4	131.95	36	339	4	150.15	37	330	4	168.35	36	321
5	132.32	37	339	5	150.51	36	330	5	168.72	37	321
6	132.68	36	338	6	150.88	37	330	6	169.08	36	321
7	133.04	36	338	7	151.24	36	330	7	169.45	37	321
8	133.40	36	338	8	151.60	36	330	8	169.81	36	320
9	133.77	37	338	9	151.97	37	330	9	170.18	37	320
630	134.13	36	338	680	152.33	36	329	730	170.55	37	320
1	134.49	36	338	1	152.70	37	329	1	170.91	36	320
2	134.86	37	338	2	153.06	36	329	2	171.27	36	319
3	135.22	36	337	3	153.42	36	329	3	171.64	37	319
4	135.59	37	337	4	153.79	37	329	4	172.00	36	319
5	135.95	36	337	5	154.15	36	329	5	172.36	36	319
6	136.31	36	337	6	154.51	36	328	6	172.73	37	319
7	136.68	37	337	7	154.88	37	328	7	173.09	36	319
8	137.04	36	337	8	155.24	36	328	8	173.46	37	318
9	137.40	36	336	9	155.60	36	328	9	173.82	36	318
640	137.77	37	336	690	155.97	37	328	740	174.19	37	318
1	138.13	36	336	1	156.33	36	327	1	174.55	36	318
2	138.50	37	336	2	156.70	37	327	2	174.92	37	317
3	138.86	36	336	3	157.06	36	327	3	175.28	36	317
4	139.23	37	336	4	157.42	36	327	4	175.65	37	317
5	139.59	36	335	5	157.79	37	327	5	176.01	36	317
6	139.96	37	335	6	158.15	36	326	6	176.38	37	317
7	140.32	36	335	7	158.52	37	326	7	176.74	36	317
8	140.69	37	335	8	158.89	37	326	8	177.11	37	316
9	141.05	36	335	9	159.25	36	326	9	177.47	36	316
650	141.41	36	335	700	159.62	37	326	750	177.84	37	316

v	$F(v)$		$10^6 K(v)$	v	$F(v)$		$10^6 K(v)$	v	$F(v)$		$10^6 K(v)$
750	177.84		316	800	196.07		306	850	214.31		297
1	178.20	36	316	1	196.44	37	306	1	214.67	36	297
2	178.56	36	316	2	196.80	36	306	2	215.03	36	296
3	178.93	37	315	3	197.16	36	306	3	215.40	37	296
4	179.29	36	315	4	197.53	37	305	4	215.76	36	296
5	179.66	37	315	5	197.89	36	305	5	216.13	37	296
6	180.02	36	315	6	198.26	37	305	6	216.49	36	296
7	180.38	36	315	7	198.62	36	305	7	216.86	37	296
8	180.75	37	314	8	198.99	37	305	8	217.22	36	296
9	181.11	36	314	9	199.35	36	304	9	217.59	36	295
760	181.48	37	314	810	199.71	36	304	860	217.96	37	295
1	181.84	36	314	1	200.07	36	304	1	218.32	36	295
2	182.21	37	314	2	200.44	37	304	2	218.69	37	295
3	182.57	36	313	3	200.80	36	304	3	219.05	36	294
4	182.94	37	313	4	201.17	37	303	4	219.42	37	294
5	183.31	37	313	5	201.53	36	303	5	219.78	36	294
6	183.67	36	313	6	201.90	37	303	6	220.15	37	294
7	184.04	37	313	7	202.26	36	303	7	220.51	36	294
8	184.40	36	312	8	202.63	37	303	8	220.88	37	293
9	184.77	37	312	9	202.99	36	302	9	221.24	36	293
770	185.13	36	312	820	203.36	37	302	870	221.60	36	293
1	185.50	37	312	1	203.72	36	302	1	221.97	37	293
2	185.86	36	312	2	204.09	37	302	2	222.33	36	292
3	186.23	37	312	3	204.45	36	302	3	222.70	37	292
4	186.59	36	311	4	204.82	37	302	4	223.06	36	292
5	186.96	37	311	5	205.18	36	301	5	223.43	37	292
6	187.32	36	311	6	205.55	37	301	6	223.79	36	291
7	187.68	36	310	7	205.91	36	301	7	224.16	37	291
8	188.05	37	310	8	206.28	37	301	8	224.52	36	291
9	188.41	36	310	9	206.64	36	301	9	224.89	37	291
780	188.78	37	310	830	207.01	37	300	880	225.25	36	291
1	189.14	36	310	1	207.37	36	300	1	225.62	37	291
2	189.51	37	310	2	207.74	37	300	2	225.98	36	291
5	189.57	36	310	3	208.10	36	300	3	226.35	37	290
4	190.24	37	309	4	208.47	37	300	4	226.71	36	290
5	190.61	37	309	5	208.83	36	299	5	227.08	37	290
6	190.97	36	309	6	209.20	37	299	6	227.44	36	290
7	191.33	37	309	7	209.56	36	299	7	227.81	37	290
8	191.69	36	309	8	209.93	37	299	8	228.17	36	289
9	192.06	37	308	9	210.29	36	299	9	228.54	37	289
790	192.42	36	308	840	210.66	37	299	890	228.90	36	289
1	192.79	37	308	1	211.02	36	298	1	229.27	37	289
2	193.15	36	308	2	211.39	37	298	2	229.63	36	289
3	193.52	37	308	3	211.75	36	298	3	230.00	37	289
4	193.88	36	308	4	212.12	37	298	4	230.36	36	288
5	194.25	37	307	5	212.48	36	298	5	230.73	37	288
6	194.61	36	307	6	212.85	37	298	6	231.09	36	288
7	194.98	37	307	7	213.21	36	297	7	231.46	37	288
8	195.34	36	307	8	213.58	37	297	8	231.82	36	287
9	195.71	37	307	9	213.94	36	297	9	232.19	37	287
800	196.07	36	306	850	214.31	37	297	900	232.55	36	287

v	$F(v)$		$10^6 K(v)$	v	$F(v)$		$10^6 K(v)$	v	$F(v)$		$10^6 K(v)$
900	232.55		287	950	250.80		278	1000	269.04		269
1	232.92	37	287	1	251.16	36	278	1	269.40	36	269
2	233.28	36	287	2	251.53	37	278	2	269.77	37	268
3	233.65	37	286	3	251.89	36	277	3	270.13	36	268
4	234.01	36	286	4	252.26	37	277	4	270.50	37	268
5	234.38	37	286	5	252.62	36	277	5	270.86	36	268
6	234.74	36	286	6	252.99	37	277	6	271.23	37	268
7	235.11	37	286	7	253.35	36	276	7	271.59	36	268
8	235.47	36	286	8	253.72	37	276	8	271.96	37	267
9	235.84	37	285	9	254.08	36	276	9	272.32	36	267
910	236.20	36	285	960	254.45	37	276	1010	272.69	37	267
1	236.57	37	285	1	254.81	36	276	1	273.05	36	267
2	236.93	36	285	2	255.18	37	275	2	273.42	37	267
3	237.30	37	285	3	255.53	36	275	3	273.78	36	267
4	237.66	36	284	4	255.90	37	275	4	274 15	37	266
5	238.03	37	284	5	256.26	36	275	5	274.51	36	266
6	238.39	36	284	6	256.63	37	275	6	274.88	37	266
7	238.76	37	284	7	256.99	36	274	7	275.24	36	266
8	239.12	36	284	8	257.36	37	274	8	275.61	37	266
9	239.49	37	283	9	257.72	36	274	9	275.96	36	266
920	239.85	36	283	970	258.09	37	274	1020	276.34	37	266
1	240.22	37	283	1	258.45	36	274	1	276.70	36	265
2	240.58	36	283	2	258.82	37	273	2	277.07	37	265
3	240.95	37	283	3	259.18	36	273	3	277.43	36	265
4	241.31	36	283	4	259.55	37	273	4	277.80	37	265
5	241.68	37	282	5	259.91	36	273	5	278.16	36	265
6	242.04	36	282	6	260.28	37	273	6	278.53	37	265
7	242.41	37	282	7	260.64	36	272	7	278.89	36	264
8	242.77	36	282	8	261.01	37	272	8	279.26	37	264
9	243.14	37	282	9	261.37	36	272	9	279.62	36	264
930	243.50	36	282	980	261.74	37	272	1030	279.99	37	264
1	243.87	37	281	1	262.10	36	272	1	280.35	36	264
2	244.23	36	281	2	262.47	37	271	2	280.72	37	263
3	244.60	37	281	3	262.83	36	271	3	281.09	37	263
4	244.96	36	281	4	263.20	37	271	4	281.45	36	263
5	245.33	37	281	5	263.56	36	271	5	281.82	37	263
6	245.69	36	280	6	263.93	37	271	6	282.18	36	263
7	246.03	36	280	7	264.29	36	271	7	282.55	37	263
8	246.42	37	280	8	264.66	37	270	8	282.91	36	262
9	246.78	36	280	9	265.02	36	270	9	283.28	37	262
940	247.15	37	280	990	265.39	37	270	1040	283.64	36	262
1	247.51	36	279	1	265.75	36	270	1	284.01	37	262
2	247.88	37	279	2	266.12	37	270	2	284.37	36	262
3	248.24	36	279	3	266.48	36	270	3	284.74	37	262
4	248.61	37	279	4	266.84	37	270	4	285.10	36	261
5	248.97	36	279	5	267.21	36	269	5	285.47	37	261
6	249.34	37	279	6	267.58	37	269	6	285.83	36	261
7	249.70	36	278	7	267.94	36	269	7	286.20	37	261
8	250.07	37	278	8	268.31	37	269	8	286.56	36	261
9	250.43	36	278	9	268.67	36	269	9	286.93	37	261
950	250.80	37	278	1000	269.04	37	269	1050	287.29	36	261

v	$F(v)$		$10^6 K(v)$	v	$F(v)$		$10^6 K(v)$	v	$F(v)$		$10^6 K(v)$
1050	287.29		261	1100	305.54		252	1150	323.78		245
1	287.66	37	260	1	305.90	36	252	1	324.15	37	245
2	288.02	36	260	2	306.27	37	252	2	324.51	36	244
3	288.39	37	260	3	306.63	36	252	4	324.88	37	244
4	288.75	36	260	4	307.00	37	252	4	325.24	36	244
5	289.12	37	260	5	307.36	36	252	5	325.61	37	244
6	289.48	36	260	6	307.73	37	251	6	325.97	36	244
7	289.85	37	259	7	308.09	36	251	7	326.34	37	244
8	290.21	36	259	8	308.46	37	251	8	326.70	36	244
9	290.58	37	259	9	308.82	36	251	9	327.06	36	243
1060	290.94	36	259	1110	309 19	37	251	1160	327.43	37	243
1	291.31	37	259	1	309.55	36	251	1	327.79	36	243
2	291.67	36	258	2	309.92	37	250	2	328.16	37	243
3	292.04	37	258	3	310.28	36	250	3	328.52	36	243
4	292.40	36	258	4	310.65	37	250	4	328.89	37	243
5	292.77	37	258	5	311.01	36	250	5	329.25	36	242
6	293.13	36	258	6	311.38	37	250	6	329.62	37	242
7	293.50	37	258	7	311.74	36	250	7	329.98	36	242
8	293.86	36	258	8	312.11	37	250	8	330.35	37	242
9	294.23	37	257	9	312.47	36	249	9	330.71	36	242
1070	294.59	36	257	1120	312.84	37	249	1170	331.08	37	242
1	294.95	37	257	1	313.20	36	249	1	331.44	36	242
2	295.31	36	257	2	313.57	37	249	2	331.81	37	241
3	295.68	37	257	3	313.93	36	249	3	332.17	36	241
4	296.04	36	257	4	314.30	37	249	4	332.54	37	241
5	296.41	37	256	5	314.66	36	248	5	332.90	36	241
6	296.77	36	256	6	315.03	37	248	6	333.27	37	241
7	297.14	37	256	7	315.39	36	248	7	333.63	36	241
8	297.49	36	256	8	315.76	37	248	8	334.00	37	241
9	297.86	37	256	9	316.13	36	248	9	334.36	36	240
1080	298.24	36	256	1130	316.49	36	248	1180	334.73	37	240
1	298.61	37	255	1	316.86	37	248	1	335.09	36	240
2	298.97	36	255	2	317.22	36	247	2	335.46	37	240
3	299.34	37	255	3	317.59	37	247	3	335.82	36	240
4	299.70	36	255	4	317.95	36	247	4	336.19	37	240
5	300.07	37	255	5	318.32	37	247	5	336.55	36	240
6	300.43	36	255	6	318.68	36	247	6	336.92	37	239
7	300.80	37	255	7	319.05	37	247	7	337.28	36	239
8	301.16	36	254	8	319.41	36	247	8	337.65	37	239
9	301.53	37	254	9	319.78	37	246	9	338.01	36	239
1090	301.89	36	254	1140	320.14	36	246	1190	338.38	37	239
1	302.26	37	254	1	320.50	36	246	1	338.74	36	239
2	302.62	36	254	2	320.87	37	246	2	339.11	37	239
3	302.99	37	254	3	321.23	36	246	3	339.47	36	238
4	303.35	36	253	4	321.60	37	246	4	339.84	37	238
5	303.71	36	253	5	321.96	36	246	5	340.20	36	238
6	304.08	37	253	6	322.32	36	245	6	340.57	37	238
7	304.44	36	253	7	322.69	37	245	7	340.93	36	238
8	304.81	37	253	8	323.95	36	245	8	341.30	37	238
9	305.17	36	253	9	323.42	37	245	9	341.66	36	238
1100	305.54	37	252	1150	323.78	36	245	1200	342.03	37	238

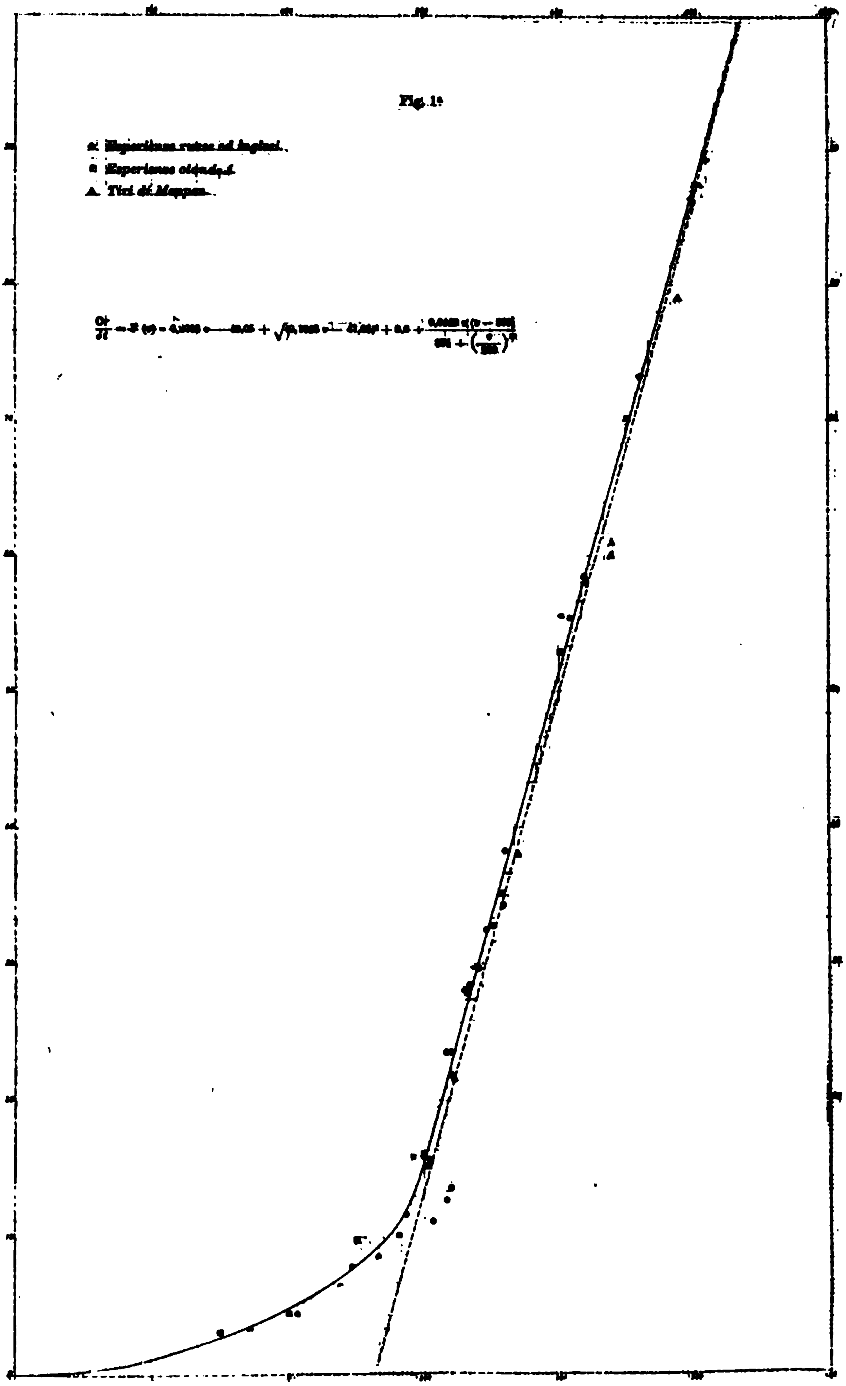
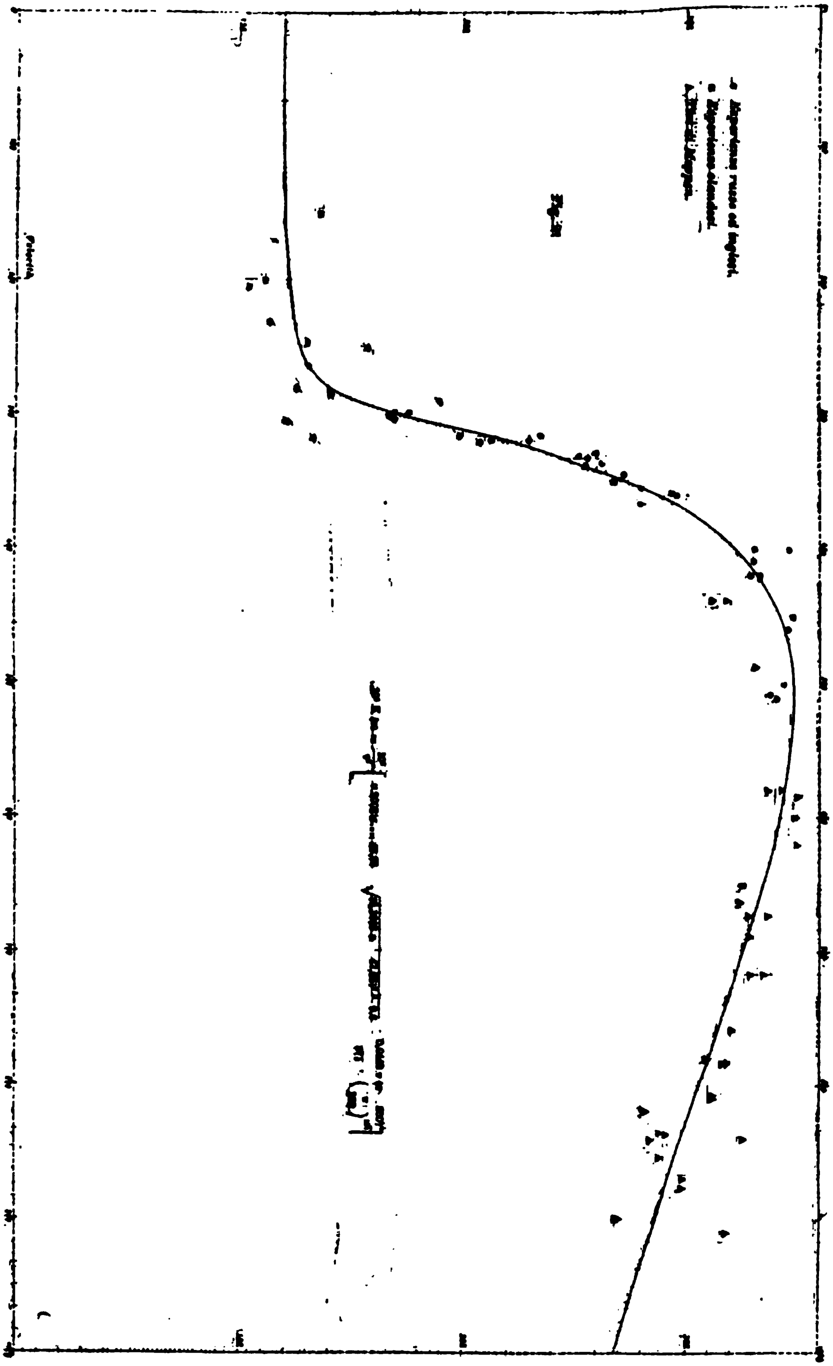


Fig. 1a
Esperienze russe ed inglesi.
Esperienze olandesi.
Tiri di Meppen.


● Expériences russes et anglaises.
■ Expériences allemandes.

PROFESSIONAL NOTES.

ARTILLERY MATERIAL.

a. Guns and Carriages.

Canet's Quick Firing Field Guns.

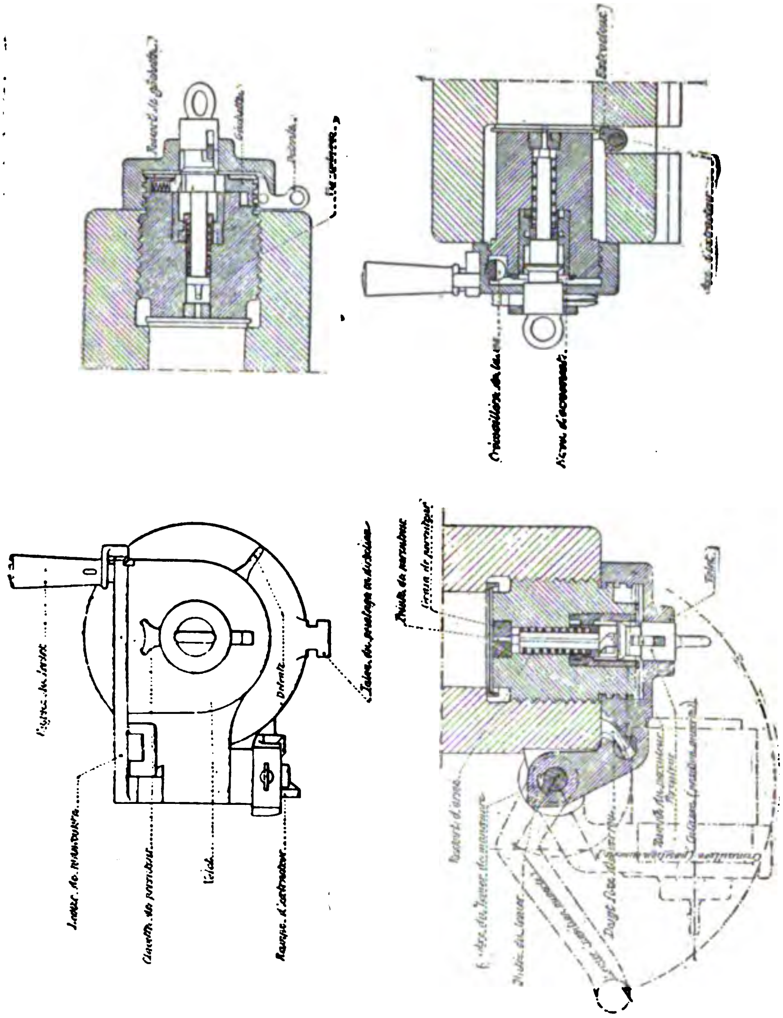
During the present year Mr. G. Canet, of the Forges et Chantiers de la Mediterranée, has produced a new class of field battery, in which an improved type of quick-firing gun is combined with a carriage, presenting several novel and important modifications. The latter, although known as the 1896 model, is the result of careful and almost continuous trials, commenced as long ago as 1889, in which year the first experiments were made by Mr. Canet on a field carriage fitted with an elastic trail, the object in view being to replace the numerous devices of holding the carriage steady under the reaction of firing. The name "flêche elastique" which Mr. Canet has given to this new system, very well defines the special features of the carriage, the trail of which consists of two cast-steel tubes, one of these being free to slide within the other under the action of the recoil; this telescopic movement is controlled by means of a friction or hydro-pneumatic brake. The outer and larger tube is attached to the side plates of the gun carriage, while the inner and smaller one terminates at its lower end with an inclined anchor-plate that is driven into the ground, and supplies the resistance necessary for running the gun out into firing position.

The practical systems of field artillery which have been introduced during the last five years may be divided into two classes, distinguished by the following features:

1. Those in which the gun is mounted on the carriage which is rigid, but to which is connected some device that limits or entirely prevents recoil, and utilizes it for bringing the gun back into firing position.

2. Those in which the carriage is rigid, and the gun is connected to it by means of some elastic or yielding device that allows a certain amount of recoil, and afterwards brings the gun back into firing position.

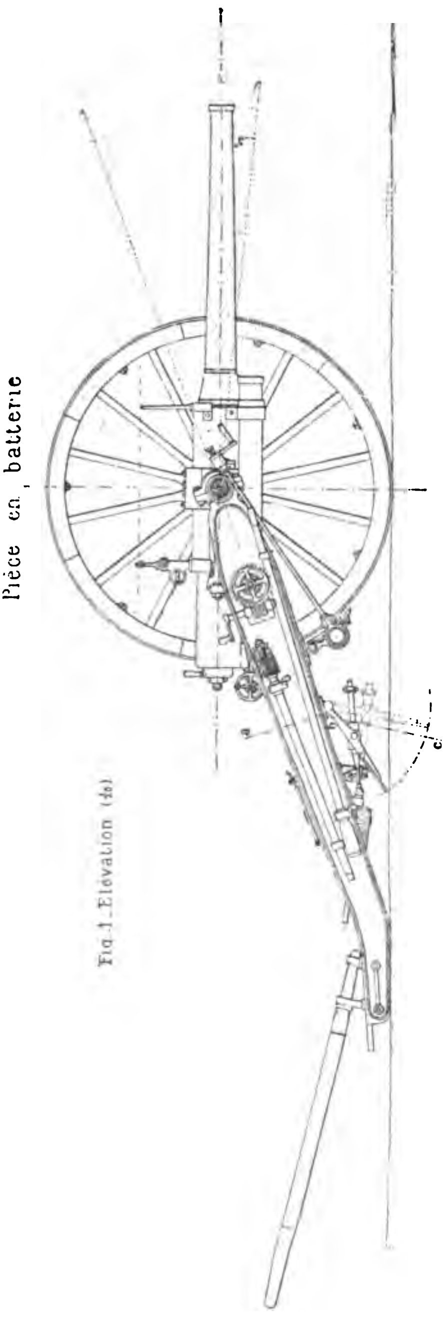
In the first system there are but few economical conditions. The advocates of this system maintain that if means are found, of placing, at any point of an ordinary carriage, a fixed or articulated anchoring device, that limits the recoil by its bearing upon the ground, and afterwards brings back the system into battery, an invaluable means of transforming a vast amount of existing material, with ease and cheapness, will have been devised. Unfortunately. up to the present time no one has been able to perfect this much desired method of transformation, and the reason is not difficult to find. The resistance set up by the anchoring device is exerted at the ground level, while the action of the gun, which tends to force back the whole system, is exerted at the level of the trunnion. Supposing, for example, that the gun is fired in a horizontal position; the carriage would tend to turn around the trail, the length of which is invariable, under the influence of a couple, in which the arm of the lever is practically equal to the height of the trunnion from the



Schneider 75 mm. Field Gun, Model 1895.

ground. As soon as the carriage is lifted, it is influenced by the force developed in the bore of the gun, in a direction inverse to the rotation of the projectile, and the carriage is subjected to a series of oscillations around the trail. As soon as the effort of lifting corresponds to the work developed by the recoil, the carriage falls, the wheels touching the ground one after the other; under such conditions the gun would have to be trained after every round, thus causing trouble and loss of valuable time.

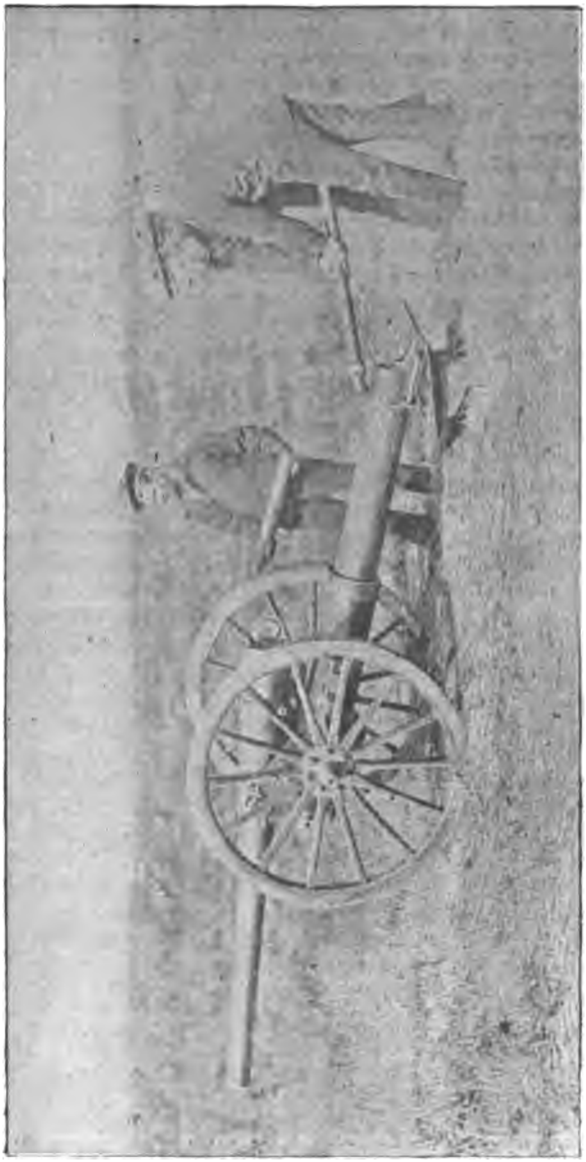
The system of independent anchoring, which is very attractive at first sight, thus throws upon the whole carriage a large and very irregular amount of work, resulting from the violent shocks to which it is unavoidably exposed. The axle springs which have to carry the whole weight of the system, are called on to withstand a constant succession of shocks, and the anchoring device itself has to resist sudden and violent strains that break the surface of



Schneider 75 mm. Field Gun, Model 1895.

the ground in which it is anchored, so that after a short time it is likely to be practically useless, and the carriage will suddenly recoil, to the danger of the men serving the gun. In order to diminish the amount of turning movement some constructors have reduced the height of the trunnions from the ground. This modification has its serious disadvantages; when the axis of the trunnions is brought below 75 centimeters from the ground, it becomes very difficult to serve the gun, and almost impossible to train it under frequently existing conditions. Driving such guns over uneven ground is also attended with serious difficulties, and even with danger to the matériel. In fact it may be said that this type of carriage does not properly fulfill any of the necessary conditions, and consequently, in spite of certain ingenious devices intended to overcome the difficulties, it cannot be considered a satisfactory method of mounting quick-firing field guns.

In the second class are included the various systems in which the gun recoils with relation to the carriage, and is supposed to be fixed upon slides, or in a cradle carrying the trunnions. In some of these devices the gun is only allowed to recoil within very narrow limits; in resisting this recoil the effort developed by the brake at each instant is very considerable, and the lifting tendency of the carriage, which is proportional to this effort, can only be overcome by an addition of dead-weight. This solution has given in some types heavier material, which is undesirable. The second solution consists in reducing the tendency of the carriage to lift, with the acceptance of a much greater length of recoil, which in its turn necessitates an increased weight of carriage, rendering the material more difficult to handle, and involving the adoption of longer slides.



Canet's 75 mm. Field Gun.

If, for example, we take as a basis for first calculation, the following data:

Weight of gun	400 kgs. (880 lbs.)
Weight of projectile	6 kgs. (13.2 lbs.)
Weight of moving cradle	50 kgs. (110 lbs.)
Initial velocity of projectile	600 meters (1968 ft.)

then the speed of the recoil may be estimated at 7.50 meters, and the work absorbed will be 1265 kilogramme-meters (9146 foot-pounds). In the first solution the recoil is limited to 50 centimeters (19.69 in.); the mean resistance of the brake will then be 2530 kilogrammes, which corresponds to a maximum pressure of about 5000 kilogrammes. In the second solution the pressure of the brake may be fixed at 1000 kilogrammes; the recoil corresponding to this pressure is 1.265 meters (49.81 in.). By either method it will be seen that stability of the carriage can only be obtained by excessive weight, and therefore by the use of material difficult to handle and more exposed to attack.

The Canet system, which we will now describe, permits, as in the previous methods, a limited recoil of the gun, but on account of its special arrangement the disadvantages above mentioned are avoided. The principal advantage claimed for the Canet system of elastic trail in a field gun mounting, is that when it is properly applied, the tendency to lift is suppressed without increasing the weight of the system. One of the principal reasons that causes a gun carriage to lift under the reaction of firing is that it takes a bearing upon a fixed point. This condition is not realized in the Canet carriage, as the resistance yields under the effort set up. Moreover, unlike all rigid systems, the length of the trail is variable, and the wheels are consequently free, during the whole period of the recoil of the moving parts, and also when the gun comes back into firing position, to remain always in contact with the ground. It will be at once understood that under these conditions the tendency to lift becomes practically *nil*, or at all events is quite negligible. This arrangement of mounting also possesses the important advantage of utilizing during recoil, almost the whole weight of the system, the fixed portion of which is reduced to the trail. Under these conditions, and without the addition of any extra weight, it becomes possible to adjust the brake in such a manner that the movable part shall be sufficiently light, for the weight of the gun and the carriage without any additional loading, to keep the wheels in contact with the ground. The effort of the recoil (all the ballistic conditions being equal) practically varies in an inverse proportion to the weight of the gun and the carriage in movement. To take an example based on the conditions above described, and assuming that the weight of the carriage moving under recoil is 500 kilogrammes (1100 lbs.), we may prepare the following comparative Table:

Weight of the gun	400 kilogs. (880 lbs.)
Weight of projectile	6 kilogs. (13.2 lbs.)
Initial velocity	600 meters (1968 ft.)

	Cradle or Slide Mounting.	Elastic Trail Mounting.
Weight of carriage moving during recoil	50 kgs.	500 kgs.
Speed of recoil	7.50 m.	3.75 m.
First solution, length of recoil	0.50 meter.	
Mean resistance of the brake	2530 kgs.	1265 kgs.
Second solution, mean resistance of the brake	1000 kilogrammes.	
Length of recoil necessary	1.265 m.	0.632 m.

These figures indicate clearly to what a large extent the problem of the use of quick-firing field guns is simplified, and how their efficiency can be increased by means of the Canet elastic trail. Experience has shown that this system can be employed with similar results as regards absence of recoil and lifting of the trail, under conditions of mobility and of power which vary very largely. This is proved by firing experiments made with three carriages of a similar type that have been recently constructed for experimental purposes.

The Canet quick-firing field guns of the 1896 model are as follows:

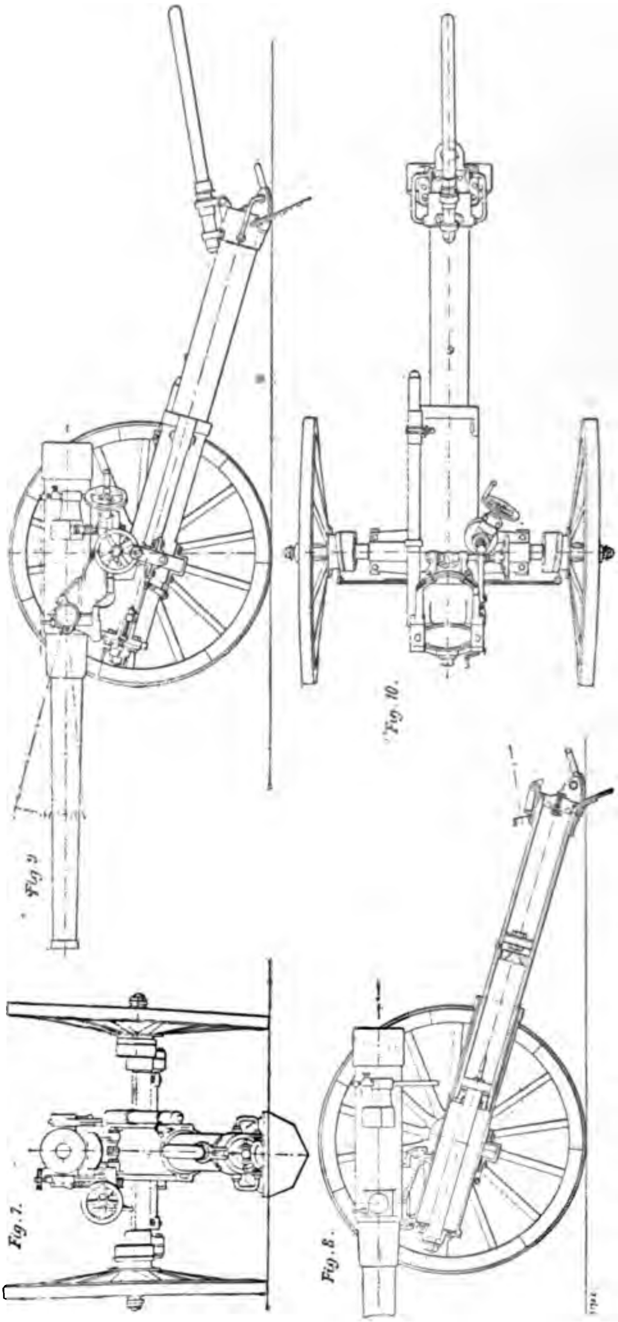
Caliber.	Heavy. Length of Bore.	Light. Length of Bore.
75 mm.	30 cal.	24 cal.
70 "	30 "	24 "
65 "	65 "	30 "

The guns themselves are constructed upon a special system, and consist of a single tube, reinforced at the rear by a long sleeve that carries the breech mechanism; there is also a ring on which the trunnions are forged, and an anchoring ring. The form and mode of construction adopted are such as to secure the best workmanship and material, especially with regard to the uniform tempering of the gun carriage. The various parts are locked together in such a manner as to insure the durability and strength of the gun, longitudinally as well as transversely. The experience obtained has demonstrated the strength and reliability of these guns in spite of their comparatively small weight.

On account of special reasons resulting from very varying conditions of service in different countries where the Canet system has been adopted, three special types of breech-closing mechanism have been adapted for these guns. In the first a cylindrical breech-block is employed, and is arranged in such a manner as to simplify as much as possible the various organs of the mechanism, and in such a way that it can be dismounted almost instantaneously by hand and without the use of any special rules. The breech is opened and closed by two direct movements of the lever. The percussion lock is set automatically—that is to say, that the main spring is drawn back during the rotation movement of the breech-block. This mechanism can be used equally well with metallic cartridge cases or plastic obturators. In the second type, the mechanism has a conical breech-block, and is operated very rapidly by the single movement of a lever always working in the same plane. A repetition firing device is employed for this gun, by which several blows can be struck on the fuze in the event of a misfire. The third type is of a very original construction, in which the two vertical and parallel sides of the block chamber are cut with semi-circular grooves, and the block swings to and fro.

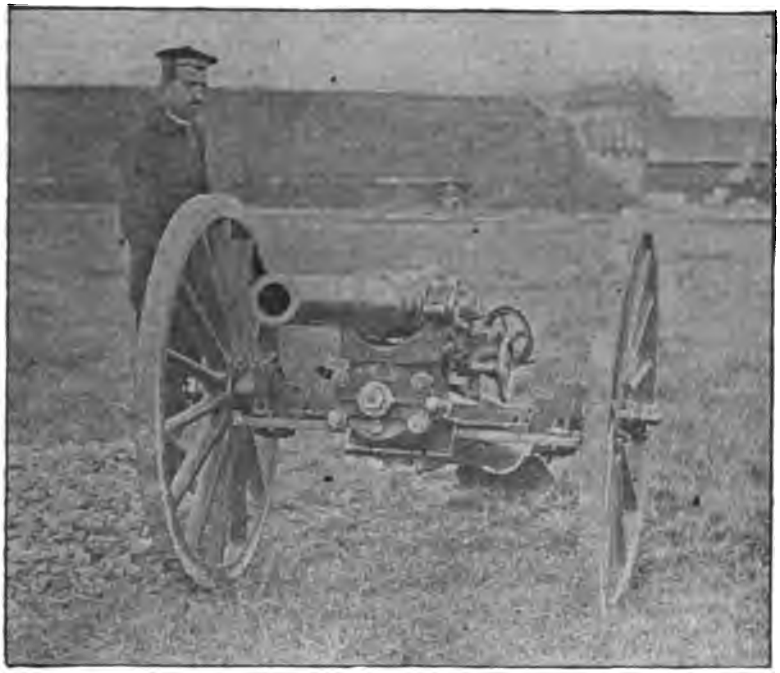
The Canet gun carriage with the elastic trail, that forms a special feature of the 1896 model, may be divided into two chief parts; the one fixed during fire, and consisting of the trail and anchor-plate; the other movable, and formed of the gun cradle mounted in grooves upon the frame of the carriage. To the moving part of the carriage is attached a steel tube (Fig. 8) that constitutes one part of the hydro-pneumatic brake. On the outer end of the trail, which is closed by a plate, is screwed a ring that carries the anchoring plate and clamps, the two flanges of the training lever, and the harnessing ring of the gun carriage. The other end of the tube enters the larger tube under the gun carriage, like the tube of a telescope.

The training lever, when the gun is being transported, rests upon the trail,



Canet's Field Gun and Carriage.

and the length is so arranged that it bears exactly against the rear face of the body of the gun carriage. In this way the system is absolutely rigid



75 mm. Canet Field Gun, Showing Brake.

during transport. This manner of fixing the training lever has the advantage of preventing a delay that often occurs in refixing the training levers in existing types.

The training mechanism consists of an endless screw gearing into a toothed segment on the gun carriage, and forming part of a horizontal shaft; on this is mounted the handwheel, by means of which the gun can be trained horizontally within a range of 4 degrees (Figs. 9 and 10). A little to the rear, and at the side of this handwheel, is a second one, which controls the vertical training movement by means of a many threaded vertical screw, on the head of which rests the underside of the gun. The preponderance of the breech block maintains this bearing in contact with the elevating screw.

The carriage is provided with a brake, to be used only when travelling on the road, and which must not under any conditions be tightened when firing. It is controlled by a handle seen at the back of the gun carriage, and by a transverse bar and two cranks. The axle is of steel, curved in the center in order to pass round the tube beneath the gun carriage; it is also bent upwards at the ends, so as to allow the use of wheels of a larger diameter than usual. According to the material preferably used in different countries, the wheels are either partly of wood and partly of metal, or entirely of iron. In either case a lubricating device of a special type keeps the bearings in good running order for several months without other attention.

The hydro-pneumatic brake controlling the recoil is of a new and very simple type, containing all the improvements resulting from the experiments that have been made with this gun carriage during the last few years. This brake insures the regular working of the gun, and requires no special attention. Its endurance has been demonstrated by a number of prolonged trials. Its position in the interior of a strong steel tube protects it from shock and all external atmospheric influences.

The operation of the gun carriage when firing is entirely automatic. At the first round the anchor plate enters the ground. According to the nature of the soil, the reaction of the first round produces a recoil which may vary, but is always insignificant, as it never exceeds 30 centimeters. This movement of the gun carriage fixes the anchor-plate in position, and with it the trail. At each subsequent round, all the moveable parts of the carriage recoil freely, telescoping upon the trail, and actuating the hydro-pneumatic brake, but without raising the wheels from the ground. As soon as the energy of recoil is absorbed, the return into firing position takes place, and the gun carriage resumes at the end of this movement the precise position it occupied before firing. The thoroughly efficient operaton of this system is in no way affected when the cannon is trained horizontally to form a lateral maximum angle of 4 degrees with the axis of the carriage. When firing is over or if a rapid change in training becomes necessary, the anchor-plate is easily disengaged from the ground.

The practical application of the principle of elastic trail by M. Canet has resulted in a gun the efficiency of which varies from 2.18 (long gun) to 2.23 (short gun).* Hitherto no quick-firing field guns, even when mounted on non-recoil carriages, have reached these efficiencies. No comparison can be made between these Canet carriages and those of the standard types in use, as the latter are little better than supports, while the former constitute an essential portion of the entire machine.

It is interesting to note, however, that the difference in efficiency is less considerable than one would expect. Thus the French standard gun carriages of the old type for 80 and 90 millimeters, when in good condition, have respectively an efficiency of 2.37 and 2.57, while the Canet system reaches an efficiency of 2.20, which may be exceeded later.

The accessories carried by the gun carriage are reduced to a sponge in two pieces, which fit one over the other. This serves for washing out or oiling the gun, or for pushing out an unexploded cartridge.

The ammunition used for the Canet quick-firing gun, model 1896, is of a new type, distinct from that now employed. It consists of the two ordinary parts, projectiles and cartridge cases, packed in separate boxes for transport. At the moment of firing the man placed near the wagon to distribute the ammunition, sets the projectile in the cartridge case by means of a special device, and passes the complete cartridges to the other numbers serving the guns. This method unites the advantages of both systems of loading, the one in which the cartrige is complete, and the gun loaded in one movement: the other, where the cartridge is separate from the projectile, and the gun is loaded in two operations; and it avoids the inconveniences attached to each.

The cartridge cases and projectiles being separately packed for transport, the boxes containing them can be stored under particularly favorable circumstances. The rims of the cartridge cases are not subject to damage, as is so often the case under ordinary circumstances, under unavoidable shocks *en route*, when they have to support the whole weight of the projectiles. It is easier, too, for the man serving out the ammunition to remove the cartridge case and projectiles separately from the box, than to handle complete cartridges that are sometimes 40 inches long.

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* These figures represent in kilogrammeters the proportion between the weight of the gun carriage and the energy expended to neutralize the force of recoil. The quick-firing gun resting upon the ground was credited until now with an efficiency less than 1.60.

The Canet cartridge cases are stamped out of brass or aluminium sheet. A percussion or electric fuze is placed in the base of the cartridge case, on the rim of which is a special device enabling the fuzes to be attached very quickly and with complete certainty. As this arrangement effectually protects the cartridge cases against injury, they can be used several times in the gun, without being repaired, and a considerable economy is thus effected.

The supply of ammunition, for 100 rounds, consists of 90 Canet shrapnel, called "projectiles uniques de campagne," and 10 large capacity steel shells for heavy charges.

The Canet shrapnel has been produced with the object of simplifying field ammunition and of replacing the various classes of projectiles now used, and each of which has its own particular service; in other words, to reduce the number of patterns. It is composed essentially of a steel envelope, inclosing a series of compressed cast-iron discs, in which are set a number of hard lead balls. A cast-iron pointed head receives the fuze and closes the projectile at its upper end. The explosive charge is contained at the back in a cavity, the sides of which are formed by a series of cast-iron rings broken in advance and closed at the top by an iron cover plate. A tube communicates with the fuze. Around this tube is heaped a substance having no explosive property, but which generates at the moment of explosion, a thick volume of smoke visible at a great distance. If the shrapnel is fired into an object containing combustible material, this substance, heated and scattered by the bursting charge, smoulders, and may give rise to a conflagration. This projectile is very compact, and possesses great longitudinal resistance. It is fitted at the base of the pointed head with an obturating ring, and near the bottom with a soft metal band that takes the rifling. The firing trials to which this shrapnel has been subjected have given the following results:

1. The smoke following the explosion is visible in most weathers to a distance of about 5000 yards.
2. Firing at a target showed a number of deep and uniformly distributed hits. This was the result of the form of construction, and demonstrates the efficiency of the projectiles.
3. The Canet shrapnel fired against ordinary masonry penetrates to a depth of 31 inches without bursting.

The heavy bursting charge shell, which is used principally for the attack of strong places, is formed of one piece of steel with a solid point. The method of fixing the fuze when required, permits of their being provided with a breach fuze without danger. Like the shrapnels they have a centring ring and a rifling band of red copper.

The fuzes are of brass or aluminium, and consist of two principal tpyes;

1. Percussion time fuzes in the rear of the cartridge for shells with heavy bursting charge.
2. Shrapnel percussion fuzes in the head of projectile, and capable of being regulated.

The adjustment of the fuzes is still one of the most delicate operations in serving the gun, and with existing means it is difficult, even to a skilful operator, to regulate with precision more than four or five fuzes per minute. This number may suffice during ordinary firing, but when rapid firing commences, the number of fuzes adjusted ought to correspond to the number of rounds the gun is capable of firing. As with the system we are considering. this number reaches 10 per minute, Mr. Canet has perfected an adjusting instrument which can without danger be put in the hands of an inexperienced man. It is in the form of shears one leg of which ends in a hood that entirely covers the fuze, while on the other runs a sliding piece, holding the blade destined to cut the slow match at the given point. A second sliding piece moves upon the lower edge of the hood, and can be fixed at any point by means of a tightening screw; it has a notch, the hollow of which is of the same form as the projecting guide pin, found upon all double-action fuzes. When the two sliding pieces have been fixed at points corresponding to the desired length of fuze, all that has to be done is to cover the fuze with the hood and press the two legs of the instrument together; this operation is instantaneous, and at any time during firing, the captain of the battery is able to check by the instrument, the fuze that had been adjusted, even if the round has been fired. Any powder now in use for field guns can be employed in the Canet quick-firing batteries.

It would be useless to give in full detail particulars of the different Canet guns of the 1896 model; two examples will suffice.

Weight of Gun and Carriage.

	Long Type.		Short Type.	
	kilos.	lbs.	kilos.	lbs.
Gun	330	726	250	550
Carriage	650	1430	500	1100
Piece in firing position	980	2156	750	1650
Canet shrapnel	5.2	11.44	4.6	10.12
Efficiency of mitraille[*]	60 p.c.		55 p.c.	
	kilos.	lbs.	kilos.	lbs.
High explosive shell	5.2	11.44	4.6	10.12
Weight of bursting charge	0.400	0.88	0.350	0.77
Complete cartridge	7	15.4	6	13.2
Weight of ammunition wagon empty	330	737	300	660
Number of rounds carried	35		35	
Weight of ammunition wagon loaded	575	1265	510	1122
Weight of gun carriage	1555	3421	1260	2772
Weight drawn per horse (6 horses)	260	570	210	462
Weight drawn per horse (4 horses)			315	693

Principal Dimensions of Gun and Carriage.

Gun length	2400 mm. (7 ft. 10.5 in.)	1800 mm. (5 ft. 10.9 in.)
Gun, length in calibers	32	24
Height of trunnions	1 m. (39.37 in.)	1 m. (39.37 in.)

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[*] The efficiency of the mitraille is in the proportion of the weight of the shrapnel to the total weight of the loaded shrapnel.

Diameter of wheels	1.320 m. (51.97 in.)	1.320 m. (51.97 in.)
Distance between wheels	1.350 m. (53.15 in.)	1.250 m. (49. 21 in.)
Training in elevation, degrees . .	— 5 to + 15	— 5 to + 15
Training in direction (right to left), degrees	5	5
Number of men necessary for serving the gun	2	2
Number of men supplying ammunition	2	2
Initial velocity	600 m. (1968 ft.)	500 m. (1640 ft.)
Maximum range	6800 m. (7400 yards.)	5000 m. (5500 yards.)

—*Engineering*, December 4 and 11, 1896.

The Hotchkiss Automatic Machine Gun.

The Hotchkiss Automatic Machine Gun in general design and in detail is a radical departure from all former types. It may be arranged to fire any of the forms of small-arms ammunition in service.

The first round is fired by hand, after which the operations of loading, firing, and extracting are carried on automatically, but under complete control of the gunner.

Slow fire may be delivered at any rate up to about 100 rounds per minute, and rapid fire up to from 500 to 600 rounds per minute. The weight of gun is 15 klg.

GENERAL DESCRIPTION.

The gun consists of a single barrel, screwed into the front of the receiver which contains the operating mechanism; below and parallel to it is secured a hollow cylinder which is in communication with the bore through a port drilled through the barrel, a few calibers from the muzzle. Contained in this cylinder is a piston on which are found suitable cams for operating the breech block, the firing, and the feed mechanism. On discharge, as soon as the bullet has passed the port connecting bore and cylinder, the powder gas enters a chamber in the front end of the cylinder and throws the piston to the rear, where it is held by an ordinary sear. On releasing the sear, by pressing the trigger, the piston is thrown forward to its initial position by the main spring. It is obvious that if the sear is held out of engagement by pressing the trigger, and the supply of cartridges be kept up, the piston will have a constant reciprocating motion.

The piston engages with the breech-block, and by its motion opens the breech, pushes the cartridge into the chamber, closes the breech and fires. On opening the breech it extracts the fired cartridge case, and brings a fresh cartridge to the loading position, performing, in other words, the functions of a soldier's hand when operating a straight-pull rifle.

The cartridges are carried in flat brass feed-strips, having a length of about 38 centimeters, and each containing thirty rounds. Each feed-strip is packed in an ordinary pasteboard box, from which it is fed directly through the gun.

The feed mechanism consists of a feed-wheel which engages in cams cut in the piston, and register with openings formed in the feed-strip; each backward and forward motion of the piston brings a fresh cartridge in line with the chamber ready to be pushed home by the breech-block and fired.

The gun is fitted with a shoulder-piece or stock, which the gunner brings to his shoulder, and with a pistol-grip and trigger for controlling the fire. Aiming and firing are therefore carried out, as in all Hotchkiss guns, with the same facility as when firing a rifle from a rest.

Two men are required to work the gun, one to load and the other to fire, but a single man can work it in case of necessity.

ACTION OF MECHANISM.

Assuming the Breech to be Closed.

The gun is loaded by pushing a feed-strip with cartridges into the feed block. The openings in the strip engage with the teeth of the feed wheel which is now secured by the pawl engaging with the ratchet, thus the first cartridge is held in position preparatory to the operation which brings it in line with the chamber and frees it from the strip. The stop which arrests the piston at the end of its backward motion is pressed down by the feed-strip and so thrown out of action.

The gun is now cocked for the first shot by drawing the piston to the rear by means of the finger-piece. This compresses the main-spring, and causes the feed-cam cut in the stem of piston to engage between two teeth of the feed-wheel. Meanwhile the locking-dog has been lifted by the unlocking-cam formed on the body of piston, and the breech-block withdrawn, the trigger engages with the sear, and the piston being held in its backward position, the gun is ready for firing.

On pressing the trigger the piston is released, and under the action of the main-spring is propelled forward, carrying with it the breech-block; this in moving forward pushes a cartridge out of the feed-strip into the chamber. When the cartridge is home the locking-cam on the piston body brings the locking-dog of the breech-block to bear against the recoil-blocks in the receiver. The breech now being closed and locked, the firing pin is driven against the primer by the tang on the piston and the cartridge is fired.

After the bullet has moved forward and passed the port connecting the bore with the cylinder, the powder gas drives the piston to the rear, withdrawing the breech-block with its extractor, and ejecting the cartridge case. The piston is now held by the trigger, the main-spring compressed, and the gun is ready for the next shot.

The teeth of the feed-wheel being engaged in the feed-cams cut in the piston stem, each backward motion of the piston turns it one tooth and draws the feed-strip forward, bringing another cartridge to the loading position.

If the trigger be held back the piston is free to move forward again under the action of the compressed main-spring, and the fire will be kept up continuously and automatically until the supply of cartridges in the strip is exhausted.

The feed-strip having been exhausted falls to the ground, and the stop which was held down by it rises and holds the piston in its backward position, independently of the trigger, and the piston is ready to move forward when the stop is again pressed down by a fresh feed-strip.

In case of a miss-fire the gun must be re-cocked by pulling back the finger-piece; the defective cartridge is ejected by this motion and the firing may be continued.

In case a soft or defective-fired cartridge case sticks in the chamber, and the gas pressure is insufficient to drive the piston back, it may be started by means of the cocking-lever, and the gun re-cocked in the usual manner.

If it be required to withdraw a partially expended feed-strip, the pawl is released from the ratchet of feed-wheel by pulling the handle, the feed-wheel is then free to turn backwards, and the strip may be pulled out. This may be done with the breech either open or closed.

If it be required to lock the gun, turn the safety lock half a turn from "fire" to the "safety" position, the piston will be secured by the eccentric-cam of the lock, either when the breech is open or closed.

The action of the mechanism depends in great measure on the pressure of the powder gas in the cylinder. The pressure may be increased by screwing down the regulator, or decreased by unscrewing the same. This varies the chamber capacity of the cylinder, and consequently the pressure.

DISTINCT AND IMPORTANT CHARACTERISTICS OF THE SYSTEM.

Simplicity.—The gun consists of but thirty-one parts (exclusive of sights), but including barrel, shoulder-piece, &c.; there are no screws or small pins, and but four springs in all, of which but one—the main spring—is essential to the working of the gun. All parts of the mechanism are so designed that it is impossible to assemble them incorrectly. No tools are necessary to dismount or assemble the mechanism, except for unscrewing the barrel and the cylinder, for which a spanner is supplied.

Ammunition Supply.—The feed mechanism is positive, and independent of gravity. The cartridges are carried in feed-strips of elastic brass, on which three rows of clips are formed which embrace and hold the cartridges at the neck, the middle of body and the head. The cartridges pack closely together, a feed-strip holding thirty rounds being only about thirty-eight centimeters long. The feed-strips are arranged to hook together, forming a continuous band when required.

The feed-strips are packed in flat pasteboard boxes, from which they may be fed directly into the gun. Packed in this manner, the feed strips stow very compactly in the ammunition boxes, and are thoroughly protected against jolting or accidental damage.

The feed mechanism is so devised that it withdraws the feed strip from the packing-box, brings the cartridges one by one, by positive motion, in line with the chamber, and ejects the empty strip. The feed works equally well at any angle of elvation or depression.

The system of loading with feed strips gives the officer far better control over the rate of fire and expenditure of ammunition than is possible by means of belts or drums.

The feed strips being made of metal are not affected by rain or dampness, they may therefore be stored any length of time without deterioration.

Safety.—The safety of the gun against accident is assured by the following features:

1. No accident through an hang-fire cartridge can occur, because the mechanism being actuated by the gas pressure, the breech remains closed and locked uutil the shot is fired.

2. The breech cannot open until the bullet has left the muzzle, because the locking-dog and breech-block are operated by the piston alone, and this latter only begins its backward movement when the bullet has passed the port and admitted gas to the cylinder.

3. Each barrel and the entire mechanism is proved with a pressure of 5000 atmospheres, whilst the highest pressure developed by small-arms ammunition rarely exceeds 3000 atmospheres.

4. The cartridges are simultaneously pushed into the chamber and fired by the action of the breech-block and firing pin, being held in the feed-strip away from any heated part of the gun until the instant of firing. This avoids all danger of excessive pressure, due to the heating of the cartridges.

Gun not Affected by Heating of Barrel.—All the moving parts of the mechanism are independent of the barrel, which is fixed to the receiver, and they remain cool after prolonged firing.

The temperature of the barrel increases rapidly during fire to about 400° C., and then remains nearly constant under continuous firing.

As shown by experiment, under prolonged firing, the action of the mechanism has in no case been interfered with by the heating of barrel.

Accuracy of Fire.—The mechanism being rectilinear in its motion, and symmetrically disposed with reference to the trunnions, these take up all the recoil and vibration, and the aim is not deranged by firing.

The gun is trained from the shoulder like a rifle from a rest, and fired at the instant of aiming by pressing the trigger.

CARE AND PRESERVATION.

No particular care besides that for keeping any small-arm in order is required for this gun. It must be kept clean and free from rust, and all parts lightly oiled. No brick-dust or gritty substances must be used on any part of the mechanism, nor must the parts be scraped with knives or roughened in any way.

If any difficulty in loading occurs, full-cock gun and load with a new feed strip.

If the gun does not eject the cartridge case, screw up the regulator a few turns; this will increase the pressure on piston and remedy the difficulty.

If recoil is felt upon shoulder, the pressure on the piston is too great, and the regulator must be unscrewed a few turns until the recoil disappears.

If the head pulls off from a defective cartridge, cock the gun, withdraw feed strip, insert defective cartridge extractor in chamber, pull trigger, re-cock gun, and the body of the cartridge will be extracted.

Although the following parts of mechanism are required for the perfect working of the gun, they are not absolutely essential, and any one, or all of them, may be broken or lost and the gun can still be fired; thus the gun will work automatically without stop, stop-spring, pawl, pawl-spring, safety-lock, trigger, sear-spring, and sear.

CARRIAGES AND MOUNTINGS.

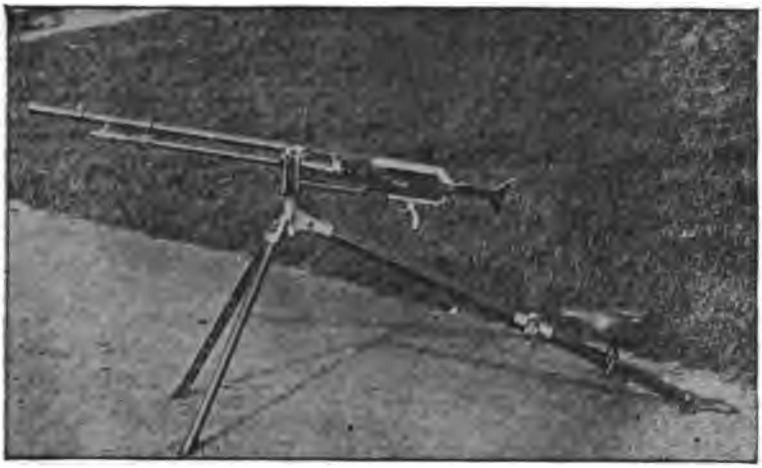
Several types of mountings for this gun have been made, both for field, mountain, and naval service.

For land service the gun is generally used with a folding tripod, and transported on pack animals.

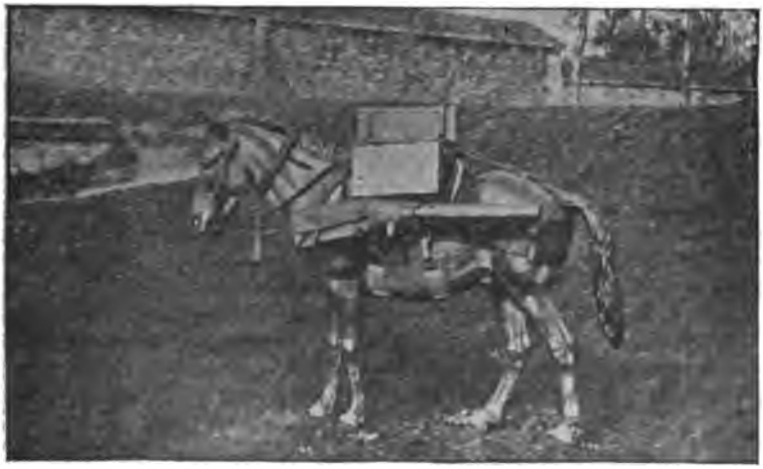
On one pack is carried the gun, the tripod, the chest of spare parts and implements, and 600 rounds of ammunition.

On each ammunition pack is carried two chests with 1920 cartridges, in feed-strips ready for firing.

The saddlery is similar to that used for light mountain artillery. Gun and tripod are carried in leather pouches secured to the saddle. They can be



Gun on Field Tripod.

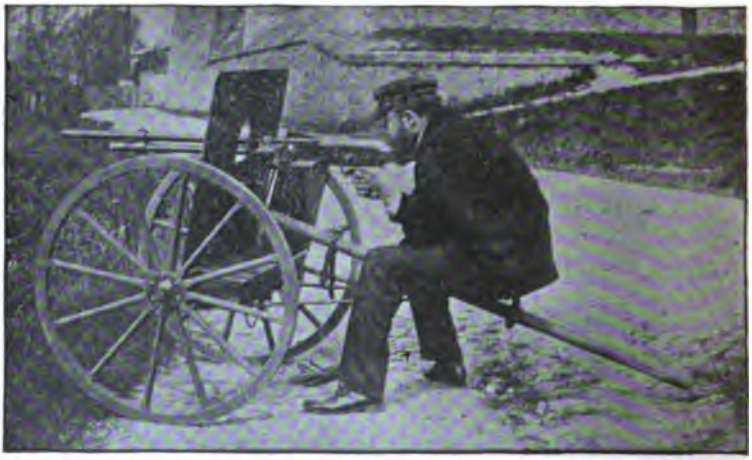


Gun Mule.

withdrawn without removing the pouches from the pack. The ammunition is carried in two chests secured above the pouches; the accessory chest is attached to the saddle frame.

The tripod consists of a socket, pivot, two legs and a trail, the latter carrying a seat for the gunner. The gun forms with the pivot and socket a universal joint, and may be laid in any direction and elevation by means of the shoulder-piece. The tripod can be converted into a litter by swinging the legs upwards, and in this form can be carried by hand over considerable distances. With the legs swung upwards the gun may be brought close to the ground and fired, the gunner lying prone.

Ammnnition Mule.



Gun on Travelling Carriage.

The tripod is fitted with an oscillator, which may be thrown in or out of gear, admitting a lateral movement up to 5 degrees.

Weight of gun pack :

(*a*). Saddlery, with gun and tripod, pouches, waterproof cover, &c	30 klg.	66 lbs.
Gun	15 "	33 "
Tripod	13 "	28.6 "
Chest, with accessories	10 "	22 "
2 chests with 600 cartridges	29 "	63.8 "
Total . . .	97 klg.	213.4 lbs.

Weight of ammunition pack:

(*b*). Saddlery, waterproof cover, &c.	23 klg.	50.6 lbs.
2 chests with 1.920 rounds	97 "	213.4 "
Total . . .	120 klg.	264 lbs.

Travelling Carriage for Land Service.—The travelling carriage consists of a shield made of special steel, capable of resisting small-arms bullets. To this shield are rivetted two axle arms carrying the wheels, and a socket and pivot. To the socket is attached a light steel tube forming the trail, the end of which is fitted with a trail eye-piece; the trail is strengthened by stays, and carries a seat for the gunner.

.1200 rounds of ammunition are carried in boxes fitted behind the shield. A light limber is provided if required, and the whole is arranged for either manual or horse draught.

b. Armor and Projectiles.

* * * * *

GENERAL MILITARY MATTERS.

The Proper Formula for Density of Loading.

Some two or three years ago, Lieutenant E. St. John Greble, 2d Artillery, first called attention to the fact, that the coefficient 27.68 used in the Formula for Density of Loading was incorrect; but by one of those peculiar manifestations of mental persistency, whereby a large number of able minds, will fail to discover a fallacy, in consequence of following a line of thought established by those whom they consider to be authorities upon the subject, every one to whom he referred the matter, myself included, refused to accept his reasoning.

The object of this paper is to demonstrate that Lieutenant Greble was entirely correct in his deductions and that the proper coefficient should be 27.70 and not 27.68 as now used.

Density of loading is considered to be unity when one gramme of powder occupies one cubic centimeter of chamber volume.

A gramme is the weight of one cubic centimeter of distilled water, weighed in vacuo at a temperature of 4° C. = 39°.2 Fahr., barometer 30″. This being the temperature at which water is at its maximum density.

The exact weight of a cubic foot of distilled water, has never been accurately ascertained. We are however only interested in the French determination, upon which the French units were based.

By this determination, a cubic inch of distilled water, weighed in vacuo at 62° Fahr. bar. 30″ weighs 252.603 grs. Troy.

$$\begin{array}{rl} \text{Log } 252.603 = & 2.4024385 \\ \text{Log } 7000 \;\;\;\; = & 3.8450980 \\ \hline \text{Log weight in lbs.} = & 8.5573405 - 10 \\ \text{Log of reciprocal} = & 1.4426595 \\ \text{Corresponding number} = & 27.7114 \end{array}$$

Therefore 1 lb. of distilled water weighed in vacuo at 62° Fahr. bar. 30″, will occupy 27.7114 cubic inches.

To reduce to the volume which one pound of distilled water will occupy at 4° C = 39°.2 Fahr. we must divide by 1.00112.

$$\begin{aligned} \text{Log } 27.7114 &= 1.4426595 \\ \text{Log } 1.00112 &= 0.0004862 \\ \hline & \quad 1.4421733 \end{aligned}$$

Corresponding number = 27.68047.

Therefore 1 lb. of distilled water at its maximum density, weighed in vacuo will occupy 27.68047 cubic inches.

This value 27.68 has heretofore been taken as the proper coefficient for transforming French to American units in computing the density of loading.

The formula for French units is:

$$\Delta = \frac{W}{C}. \qquad \text{Formula 1.}$$

In which Δ = density of loading; W = weight of powder in grammes, and C = volume of chamber in cubic centimeters.

For American units the following is usually adopted:

$$\Delta = \frac{27.68\ W}{C}. \qquad \text{Formula 2.}$$

In which W = weight in lbs., and C = volume of chamber in cubic inches.

While it is true that each pound of powder must occupy 27.68 cubic inches of space, or at that rate, in order to produce *the absolute unit density of loading*, nevertheless 27.68 is not the proper coefficient for Formula 2, which may be demonstrated as follows:

To simplify the discussion we will assume that the Standard Scale used in measuring any gun is made of the same material as the gun, and contracts and expands with the gun.

When we say that the volume of the chamber of any gun is N cubic centimeters, we do not mean that such is the case at all temperatures, as the chamber expands and contracts with varying temperatures. What we mean is, that such will be the volume, when the gun is at the French standard of temperature, viz: 0° C = 32° Fahr.

In the same manner, when we say that the volume of the chamber of a gun is N cubic inches, we mean that such will be the volume when the gun is at the U. S. standard of temperature, which is 62° Fahr.

If now we measure the volume of the chamber of a gun by a French scale, load it, and determine the density of loading by Formula 1, we will have the density of loading which will obtain when the gun is at 32° Fahr. If we again measure the same gun, with an American scale, and compute the density of loading by Formula 2, we will obtain the value for the density of loading when the gun is at 62° Fahr. and the two values will not be the same. It is therefore manifest that Formulas 1 and 2 will not give the same value for the density of loading of the same gun and charge.

In order that the density of loading of two guns should be the same at all temperatures, we must make it the same at some standard temperature. As the definition of unit density of loading was originally given in French units, it will be convenient to use the French standard for this purpose, viz: 32° F.

It is manifest that the coefficient 27.68 gives us the value at 62° Fahr. and not at 32° Fahr. and is therefore useless for purpose of comparison with the French standard.

As all our modern guns are constructed of steel, the computation necessary to determine the proper coefficient is very simple.

Let us consider a gun at 32° Fahr. and let *W* lbs. of powder be exactly sufficient to load it at unit density of loading. Then as one pound of powder must occupy 27.68 cubic inches at unit density of loading, it is manifest that when the gun is at 32° Fahr. we will have $C = 27.68\ W$ cubic inches.

If we now compute the expansion of the chamber from 32° Fahr. to 62° Fahr. remembering that a steel rod 1000 feet long, will expand 0.00763 inches for every degree of temperature Fahr. we find that the volume of the chamber at 62° Fahr. will be 27.70 *W* cubic inches.

Therefore in order to insure that each pound of powder will exactly occupy 27.68 cubic inches when the gun is at 32° Fahr. we must load it so that each pound will occupy 27.70 cubic inches when the gun is at 62° Fahr.

If we measure a steel gun with a steel scale, American standard, the scale being at the temperature of the gun, and then load so that one pound of powder, will occupy 27.70 cubic inches scale measure, we are insured that at 62° Fahr. a pound of powder will exactly occupy 27.70 cubic inches; and therefore that when the gun is at 32° Fahr. each pound will occupy exactly 27.68 cubic inches, and that the density of loading will compare exactly with that of a French gun loaded so that one gramme of powder will occupy one cubic centimeter of space.

Therefore 27.70 instead of 27.68 is the proper coefficient for Formula 2, which should read:

$$\Delta = \frac{27.70\ W}{C}$$

Of course the slight difference of 0.02 is of no practical importance; and my object is merely to present the theoretical side of the question, as there is no reason why we should not be theoretically right in this matter.

So far as I know Lieutenant Greble is entitled to the credit of having detected this error in our method of computation.

1st Lieutenant G. N. Whistler,
5th Artillery.

RANGE TABLE FOR THE 10" B.L. RIFLE,

COMPUTED BY

FIRST LIEUTENANT ALFRED HUNTER, FOURTH ARTILLERY.

Practice charge, 203 lbs B.P. Powder. Projectile, 575 lbs. $\frac{\delta_{\prime}}{\delta} = 1.$

I. V. = 1725 foot seconds.

Range, yards.	Angle of departure. ϕ.	d'	$\mp \Delta\phi$ for $\Delta V = \pm$ 50 f.s.	$\mp \Delta\phi$ for $\Delta C = \pm \frac{1}{10}$.	Drift, yards.	Deviation right or left for 10 mile per hour of even wind. Yards.	Time of flight, seconds.	Angle of fall.	Remaining velocity. f.s.	Maximum ordinate, feet.
5000	5° 54′.5	9′.1	20′.4	8.′8	10.3	8.0	10.36	7° 21′.6	1251.3	424
5100	6 3.6	9.1	21.0	9.2	10.9	8.2	10.6	7 34.2	1243.0	448
5200	6 12.7	9.2	21.4	9.6	11.5	8.5	10.84	7 47.2	1234.8	473
5300	6 21.9	9.3	21.8	10.1	12.2	8.8	11.08	8 00.5	1226.9	498
5400	6 31.2	9.4	22.3	10.5	13.0	9.0	11.32	8 13.7	1219.4	523
5500	6 40.6	9.5	22.8	10.9	13.7	9.3	11.57	8 27.4	1212.2	548
5600	6 50.1	9.6	23.3	11.4	14.5	9.6	11.82	8 41.9	1205.0	573
5700	6 59.7	9.6	23.8	11.9	15.3	9.9	12.06	8 55.0	1198.0	599
5800	7 9.3	9.7	24.3	12.4	16.1	10.2	12.30	9 9.4	1191.1	624
5900	7 18.9	9.7	24.9	12.9	16.9	10.5	12.55	9 25.9	1184.2	650
6000	7 28.6	9.7	25.4	13.4	17.8	10.8	12.8	9 38.6	1176.1	676
6100	7 38.3	9.8	26.0	13.9	18.5	11.3	13.15	9 53.5	1171.6	705
6200	7 48.1	9.9	26.6	14.5	19.2	11.7	13.43	10 6.8	1164.7	734
6300	7 58.1	10.1	27.3	15.1	20.0	12.1	13.69	10 22.1	1159.0	763
6400	8 8.1	10.2	27.8	15.7	20.8	12.5	13.96	10 37.8	1153.8	793
6500	8 18.3	10.4	28.5	16.3	21.8	12.9	14.21	10 52.4	1148.6	825
6600	8 28.7	10.5	29.2	16.9	22.6	13.3	14.49	11 8.4	1143.7	858
6700	8 39.2	10.6	29.8	17.5	23.4	13.7	14.77	11 25.0	1136.9	891
6800	8 49.8	10.7	30.6	18.2	24.3	14.2	15.08	11 41.4	1130.9	926
6900	9 0.5	10.8	31.3	18.9	25.2	14.6	15.32	11 58.0	1125.9	964
7000	9 11.3	10.9	32.0	19.6	26.2	15.1	15.6	12 14.3	1121.6	1005
7100	9 22.2	11.0	32.7	20.3	27.2	15.5	15.88	12 37.3	1116.3	1034
7200	9 33.2	11.1	33.4	20.9	28.2	16.0	16.16	12 48.5	1111.3	1074
7300	9 44.3	11.1	34.0	21.4	29.3	16.5	16.45	13 5.5	1106.3	1113
7400	9 55.4	11.2	34.6	22.3	30.2	16.9	16.72	13 24.2	1102.2	1151
7500	10 6.6	11.2	35.2	23.0	31.2	17.4	17.0	13 39.2	1097.8	1184
7600	10 17.9	11.4	35.8	23.7	32.2	17.9	17.31	13 55.4	1093.4	1231
7700	10 29.3	11.5	36.3	24.5	33.2	18.5	17.58	14 12.3	1090.3	1278
7800	10 40.8	11.5	37.2	25.3	34.2	19.0	17.85	14 27.0	1087.2	1335
7900	10 52.3	11.6	37.7	26.1	35.3	19.6	18.13	14 44.5	1084.0	1373
8000	11 3.9	11.6	38.2	26.9	36.4	20.1	18.41	15 2.1	1081.0	1420
8100	11 15.5	11.7	38.8	27.7	37.5	20.7	18.70	15 20.0	1078.0	1467
8200	11 27.2	11.8	39.4	28.5	38.9	21.3	19.0	15 38.2	1075.1	1515
8300	11 39.0	12.0	40.0	29.3	40.5	21.9	19.3	15 57.0	1072.4	1564
8400	11 51.0	12.1	40.6	30.1	42.0	22.5	19.61	16 15.0	1069.3	1614
8500	12 3.1	12.3	41.2	31.0	43.4	23.1	19.92	16 34.8	1066.5	1665
8600	12 15.4	12.5	41.8	31.9	44.7	23.8	20.24	16 54.0	1063.8	1716
8700	12 27.9	12.6	42.4	32.8	46.0	24.5	20.56	17 14.2	1061.0	1768
8800	12 40.5	12.7	43.0	33.7	47.3	25.1	20.87	17 34.8	1058.2	1723
8900	12 52.2	12.9	43.7	34.7	48.6	25.7	21.18	17 56.0	1055.4	1879
9000	13 6.0		44.4	35.7	50.0	26.4	21.5	18 12.8	1052.8	1936

The angles of departure are corrected for the height of the trajectory.

BOOK REVIEWS.

Memoirs of Marshal Oudinot, Duc de Reggio, compiled from the hitherto unpublished souvenirs of the Duchesse de Reggio, by Gaston Stiegler, and now first translated into English by Alexander Teixeira de Mattos. New York: D. Appleton and Company, 1897. Pp. 474. $2.00.

The Duchesse de Reggio from whose souvenirs these memoirs have been compiled was the second wife of Oudinot, whom he married just before the Russian campaign of 1812, and who outlived him. Oudinot's services before 1812 are consequently very briefly stated, but, on the other hand, from 1812 until his death in 1847 we have very full accounts of his official and private life in these pages.

Oudinot was the son of a brewer at Bar-le-Duc and was intended by his parents for trade, but at seventeen he enlisted, although his mother soon brought him back again. In 1791 he was elected to the command of a battalion as lieutenant-colonel, becoming colonel in 1793. The officers of his new regiment being all noblemen by birth felt aggrieved at serving under a colonel of modest parentage, but after the first fight none thought of repudiating a colonel so brave.

"One day, in his old age, when he was relating this anecdote, some one remarked how he must have loved those brave men, who had been able so quickly to stifle their prejudices. 'Ah, you asked me if I loved them!' he exclaimed, eagerly, 'I should think I did love them! I got them all killed!'"

In 1794 he was nominated general of brigade, and in 1799 general of division. For his personal bravery at Pozzolo and Monzembano, 26th December, 1799, Bonaparte presented him with a sword of honor and the cannon he had captured. In 1805 he and Lannes, by their personal bravery saved the Thabor Bridge, in presence of the enemy, and made the French master of it without firing a shot.

At Wagram in the morning Oudinot received orders not to attack, but after Davout occupied the heights of Neusiedel he saw that the situation was changed, and in disobedience of orders carried the heights at Wagram.

"The next day Napoleon said to Oudinot:

"'Do you know what you did yesterday?'

"'I trust Sire, I did not too badly do my duty.'

"'What you did was . . . . you deserved to be shot!'

"Some days later, in a letter to the Minister for War, dated Schönbrunn, 29th July, 1809, the Emperor expressly says:

"'It was General Oudinot who took Wagram on the 6th, at mid-day.'"

Soon after he was promoted to the rank of Marshal.

His personal bravery and his fiery temper always led him into the thick of the fight: he was wounded by shot eleven times and received nine sabre cuts on his body. Indeed, we owe much of these interesting memoirs to the fact that he was so often wounded; and the most vivid description in the book, the retreat from Moscow, we have from the pen of his wife because she journeyed all the way to Wilna to nurse him after his grape-shot wound received at Polotsk, and then remained to carry him home after his wound received at Beresina, thus bringing her along with the remains of the Grande Armée.

Oudinot did not join Napoleon during the hundred days. In the fall of 1815 he became major-general, commander-in-chief of the national guard and a marshal of France.

The position of Oudinot's wife as Mistress of the Robes threw them both into very intimate relations with the royal family, and much interest consequently attaches to the later memoirs on this account.

The general character of the memoirs differs somewhat from the other works of this kind, in that the same discretion which was the secret of the Duchesse de Reggio's success at court, marks the pages of this book.

"Lovers of scandal, close this book! Its charm is not that of malice."

It is a simple straight-forward story, usually cold and indifferent, but rising to deep feeling at times.

The publishers have presented the volume in attractive form, adorned with two portraits in heliogravure.

J. P. W.

The new Polarizing Photo-Chronograph. Being an account of experiments at the U. S. Artillery School, Fort Monroe, Va., in developing this instrument. By Albert Cushing Crehore, Ph. D. Assistant Professor of Physics, Dartmouth College, and George Owen Squier, Ph. D. 1st Lieutenant of Artillery, U. S. Army. New York: John Wiley and Sons. London; Chapman and Hall.

The title of this book expresses well enough, perhaps, what is treated of between its covers, but anyone interested in original experimental work, especially artillerymen with a scientific inclination, will find more than ordinary interest, satisfaction and edification in a careful perusal of its pages.

It has been a long time since we have had laid before us, on this side, so satisfactory an account of original experimenial work within the limits of the military field. It is believed we must go back to General Abbot's experiments on sub-marine mine explosions, or still further back to the experiments of Rodman and Mordicai before we may halt for classification or comparison.

Briefly stated, the book is an account of the development of a new velocimeter and general chronograph of greater delicacy than any other heretofore in use, which registers on a photographic plate the passage of a projectile at several points of its trajectory and at the same time reproduces along side this photograph a twin scale, so that a parallel, permanent record of the time-space relation is established for future reference and study at the liesure of the experimenter.

The salient feature of the method is the ingenious and beautiful manner in which a rather out of the way scientific fact has been harnessed and made to do useful work. This fact is the well known action of polarized light with two Nicol prisms, associated with the discovery of Faraday that by passing the polarized beam through certain substances situated in a strong magnetic field, and in such a direction as to coincide with the lines of magnetic force the plane of polarization is rotated. In this case the polarized beam after leaving the first Nicol prism is made to pass through a tube containing carbon bisulphide around which the electric wire is coiled which produces the magnetic field when the current is running. From this tube the beam passes on to the second prism, or analyzer, which arrests the beam completely when there is no current. If a current be sent through the coil about the tube of bisulphide the plane of the polarized beam is rotated to such an angle as to allow light to pass through the analyzer. Under this condition the beam passes on and falls on a small slit in the case of a photographic camera which, in experimenting, opens automatically at the proper time and permits the beam to fall on the photographic plate which is rapidly rotated by means of an independent electric motor; when, therefore, the current is on in the coil, a circular band of light will be photographed on the plate. If the current be interrupted by a projectile passing through a ballistic screen, or by any other event, the plane of the polarized beam instantly rotates to its normal position and all light is arrested by the analyzer prism. At these times the bright band on the photographic plate is interrupted by corresponding dark spaces.

The time scale is produced on the photographic plate by light from an independent source, first falling on a mirror placed in such a position as to cause the reflected beam to fall on one of the prongs of a tuning-fork which is kept in vibration by an electro-magnet; the beam then passing on through the slit in the camera case strikes the plate and causes the photograph of the shadow of the edge of the prong of the tuning-fork to be recorded as a circular sinusoidal band about the center of rotation, parallel to the band produced by the polarized beam coming from the analyzer prism above described. The vibration of a tuning-fork thus gives the time scale.

A specially designed angle-measuring instrument is described in connection with the completed chronograph, which enables the experimenter to read the angles on the negatives with great precision.

The remarkable delicacy of the method and apparatus is evidenced by the fact that, even with the earlier crude apparatus, as many as seven distinct velocity records were registered on the photograhic plate while the projectile traversed only 1 foot 10½ inches in the bore of the gun (3.2-inch field gun), the distances between consecutive seconds being as small as 1.48 inch, and corresponding to a time interval of about 0.0005 second. In ballistic firing for records outside the gun the distance between screens was 5 feet, giving ten velocity records within 50 feet of the muzzle.

It is not surprising that such a long step forward into unexplored regions as this should have brought to light some new facts. Among these may be specified the definite determination of the increase of velocity after the projectile leaves the gun. Under the conditions of their experiments it was found that the point of maximum velocity was "at six or seven feet from the muzzle of the gun—certainly more than five feet and less than ten—or about twenty-five calibers in front of the muzzle."

The experiments inside the bore revealed the fact that the form of the velocity-time function appeared, from its plotting, to approximate more nearly to a right line than to any curve, and when this form of the function was assumed, the space-time function took, as a consequence, the form of a parabola. Plates accompany the text which show these relations closely plotted for several shots.

After giving an account of the first experiments with crude apparatus, the book proceeds to give a description of the chronograph in its final form, as made for the Board of Ordnance and Fortification, U.S. Army. This instrument is now installed at the Artillery School at Fort Monroe, Va. Then follows an account of some experiments with this new instrument which illustrate its adaptability to a new line of analysis of the alternating current when under the influence of an harmonic electro-motive force suddenly introduced into the circuit, a subject to which Dr. Crehore has given special attention.

The appendix contains a reprint of Dr. Crehore's paper on "A Reliable Method of Recording Variable Current Curves," which may be regarded as the germ of the chronograph and the experimentation connected therewith, for it was due to the fact that Lieutenant Squier appreciated the bearing of this paper on the measurement of the velocities of projectiles that the two experimenters were brought together and their work undertaken.

The text is generously supplemented with photographic reproductions of the earlier apparatus and the completed instrument, and of many negatives of velocity records and alternating current phenomena.

E. M. W.

Fünf Taktische Aufgaben über Führung und Verwendung der Feld-Artillerie. Gustav Smekal, K. und K. Hauptmann des Generalstabs-Corps. 1 Heft. Wien, 1897: L. W. Seidel & Sohn. $1.00. Pp. 103, with 5 maps.

Tactical problems, or practical exercises illustrating the principles of tactics, to be solved on the map, either in-doors or on the ground itself, constitute the best means of teaching the subject of tactics. These exercises are conducted with the officers under instruction alone—not with troops,— and are intended to *teach* the principles of the use of artillery in the field, to *fix* in the mind the rules set forth in drill and firing regulations, and to *prepare* the officers for their actual duties in the field, at maneuvers and in war.

Problems relating to infantry and cavalry, and incidentally to field artillery, are common enough, but the only collection of problems relating directly and specially to field artillery, other than the one before us, with which we are acquainted, is one published several years ago by the instructor at the French General Staff School in the *Revue d' Artillerie*.

The first number discusses the conduct of a single battery, the second will consider that of the artillery of an independent infantry division, the third that of single horse battery, the fourth that of the division artillery of a cavalry division and the fifth that of an artillery mass, composed of several groups of batteries.

The work is divided into three parts: (1) the statement of the problems to be solved, (2) the solution of the problems, (3) the discussion of the solutions.

In the first part the general situation is first given,—a detachment (5 battalions, 1 squadron, 1 battery) moving out to find and attack the enemy; then follow eighteen separate questions (problems), most of them addressed to the officers of the battery, arranged in succession to conform to the progress of the advance and the development of the battle, and involving in detail the conduct of each officer connected with the battery.

The manner in which these problems are to be dictated to the officers under instruction, how and where they are to be solved, and the time allowed for the solution are carefully prescribed.

The second part contains the solutions of the separate problems in full. As these problems were all actually solved with officers under instruction, these solutions have a special value.

The third part has for its object to call attention to the errors most commonly committed, to investigate the cause of these mistakes, and to refer to regulations and other authorities for confirmation of the views expressed.

The author is a captain in the General Staff Corps assigned to duty with an infantry regiment. It must be remembered that the officers of the General Staff are not merely bureau officers, but also practical field soldiers in the highest sense. After a tour in the various offices they are sent to duty with troops to be tested practically. Therefore, these problems are not the result of mere theory, but are the outcome of experience in the field. Nevertheless, there are a number of points in the problems before us, which appear to us subject to criticism.

In the first place, it is not clear why (in the assumptions made) the infantry does not promptly gain possession of the heights on approaching the enemy, but remains concentrated in the low ground; nor does it seem proper that the reconnoissance conducted by the cavalry should cease entirely as soon as the battle opens; finally, the supposition that the artillery takes but one position (2600 paces) will hardly be upheld by good authority. Of course, these remarks refer only to the situation and movements as assumed, not to the solutions of the problems under these assumptions. The latter are worthy of all praise.

On the whole, the work is interesting and valuable and constitutes not only for artillery officers, but also for officers of other arms, an excellent and extremely useful study. It is an invaluable aid to the study of tactics and drill and firing regulations, and the method involved is the very best means of making good, practical, efficient light artillery officers, ready for actual service in the field.

The maps are taken from the government survey maps, made by the Military Geographical Institute of the General Staff,--among the best maps in existence.

J. P. W.

Cavalry Studies From Two Great Wars. International Series, No. 2, Edited by Captain Arthur L. Wagner, Sixth Infantry. Kansas City, Mo., Hudson-Kimberly Publishing Company. Pp. 267. Price $1.00.

The three monographs presented in this volume give us a very fair idea of the lines along which the use of cavalry in war has been developed in the past thirty or thirty-five years, for the principles accepted to-day are the outcome of the two great wars of 1861-5 and 1870-1, those of 1866 and 1877-8 having added little of value for this arm.

The essay on "The Operations of the Cavalry in the Gettysburg Campaign," by Lieutenant-Colonel George B. Davis, now Professor of Law at the United States Military Academy, should really come first in order. Although, as the author states, the subject is treated from the point of view of the *strategic* use of the arm, nevertheless, the points of value relating to its *tactical* use are clearly brought out, and the lessons taught are summed up as follows:

"Up to this time the practice had been to maintain a chain of infantry outposts along the front and flanks of an army in the vicinity of the enemy. Cavalry had been been neither freely nor boldly used, and outpost duty had, as a rule, been timidly and inefficiently performed. * * * In the two great wars just preceding our own, in the Crimea and in Italy, this state of the case was true to a remarkable degree. This was largely due to the fact that the cavalry had been fractioned up and distributed among the larger units of infantry. The same thing was attempted in the Army of the Potomac, but, after a year's experience, the attempt was abandoned; the cavalry was withdrawn from the infantry corps and concentrated, first in a division, then a corps of three divisions, acting under the orders of the commanding general.

"In this campaign we have the first example of the outpost work of an army done by the arm best fitted for the task. * * * In the performance of these duties, we have seen that there were several collisions. If the tactical details of these encounters be carefully and thoroughly studied, I think the fact will appear that while there was much fighting on foot, it was not so generally successful as has been supposed. I think the fact will also appear that the command was most frequently and uniformly successful which was most skillfully handled *as a mounted force*—dismounting only to accomplish a temporary purpose, or, as in Buford's case at Gettysburg, when it was necessary to oppose infantry, or to hold a point of great strategic importance until the infantry could arrive."

The article on "The French Cavalry in 1870 with its Tactical Results" by Lieutenant-Colonel Bonie, is the basis on which the present French Cavalry has been re-organized and developed. It is a fearless criticism by an eye-witness of all the faults of the old system, and constitutes one of the most valuable contributions to the literature of the subject.

The Third paper, "The Cavalry in the Battle of Vionville and Mars-la-Tour" by Major Kaeler of the Great General Staff, is here presented in the English language for the first time, in an excellent translation by Lieutenant Carl Reichman, of our army. It is a careful review of the events, studied with the aid of the official records.

The entire work is essential to the military student who desires to keep pace with the progress of tactics, and well-nigh indispensable to the cavalry officer who expects to handle his arm properly in the field.

J. P. W.

Aperçu Critique des Passage du Danube pendant les Guerres Turco-Russes depuis 1828. Par un Officier Supérieur Turc. Constantinople: Otto Keil, 1896. Pp. 57.

The Danube from Orsova, on the Hungarian frontier, to the Black Sea, is the portion considered in this pamphlet. It offers the greatest example of the defense and the passage of rivers which history furnishes.

The author, a field officer of the Turkish army, considers the passage of the Danube in 1828-1829, in 1853-1854 and in 1877. In each of these campaigns the first question invariably was, how to cross the Danube on the one side, how to defend it and prevent the passage on the other. In none of these campaigns did the Russians experience any serious resistance. In 1877 the passage took place at Galatz and at Simnitza, and in regard to this campaign the author says:

"But, in conclusion, it must be acknowledged that the Russian army of operation which crossed the Danube was not, in point of numbers, in condition to make an offensive movement. Its too widely extended front might perhaps have been of use if there had been other subdivisions which, immediately after the passage of the troops referred to, could have crossed the Danube to establish themselves in Bulgaria; but as these did not exist, the passage as made could only have led to disaster, had it been opposed by a general who comprehended his duty. * * *

"Small bodies of troops protected by the darkness and embarked on rafts, boats or potoons, can easily cross a river without thereby changing the strategical situation; but for a large enterprise a bridge is always necessary, and such a bridge could only be constructed between Nicopolis and Sistow. If then, Abdul-Kérim Pasha had been familiar with the geography of the Danube, this fact could not have escaped his observation.

"Finally, to cite only celebrated examples, the fact that the Turkish general-in-chief had not been able to disabuse his mind of the fixed idea that the Russians wished to cross the Danube between Roustchouk and Tortokan, a notion which does not even rest on an historic basis, resembles somewhat the case of Wellington, who long after Waterloo always insisted upon it that Napoleon's plan was to cut him off from the sea."

The essay is useful not only as a study in strategy, but also a source of information in technical and economical matters relating to the building of bridges and the transportation of troops across rivers under difficulties.

J.P.W.

Die Anwendung der Photographie zu Militärischen Zwecken. Bearbeitet von Kiesling, Premir-Lieutenant a.D., Halle a.S.: Wilhelm Knapp, 1896. Pp. 100.

This pamphlet on the military application of photography, constitutes Part 19 of the *Encyclopedia of Photography*, but is complete in itself. It gives a résumé of the use of photography for military purposes, although in no sense a hand-book for practical use in photography.

Beginning with the discovery of photography in 1839 by Daguerre and Niepse (the latter a cavalry officer), we are led through the various stages of the art and its applications in reproducing maps, in photo-grammetry, in balloon photography, in reconnoissance, and in photographing projectiles in motion and the recoil of guns, up to the present time.

In the reproduction of maps we call attention only to the latest development, viz: the field photograph detachments of the English field telegraph sections, whose duty it is to reproduce maps in the field. If, for example, only a general map of a district on a small scale is available, an enlarged map is produced on a larger scale, and used by the officers on reconnoissance to sketch in the details.

The use of photography in topographical surveying is discussed in a brief article which does not do justice to the subject: the late uses of this method in Canada (see Professional Notes, *Journal U.S. Artillery*, March-April, 1897) promise considerable future use for this process.

Balloon and kite photography is well described in two very interesting sections, and illustrated by actual photographs of landscapes taken from them. The latest invention in this line is a kite which may be rolled up and carried in the pocket, and on which when flying the camera is carried.

Microscopic photography, which found its application during the siege of Paris, in reducing letters and despatches to microscopic proportions with a view to sending them out by carrier pigeons, forms the subject of another section.

But the most interesting articles are those on photographing moving projectiles, which not only aid us in determining the positions of the projectile in its flight and the conical motion of the point, but also exhibit the air waves and whirlpools in front of and behind the projectiles.

Altogether this pamphlet contains much valuable matter and is the only complete recent account of what has been accomplished for the military profession by photography.

J.P.W.

Hints on Stable Management by Captain M. F. Rimington, Iniskilling Dragoons. Gale & Polden, Ltd., Aldershot. Pp. 72. Price one shilling, post free.

This booklet is intended to assist young officers and sergeants in maintaining the horses under their charge in a healthy and fit condition, ready for hard work when the pinch comes, and is the result of years of experience by the author, at home and abroad, with horses living under varied conditions, and used for many different purposes.

The subject-matter treats of forage and its selection, of different methods of conditioning horses, of grooming, shoeing and the general care of horses, of proper bitting, and of various precautions on the march and in camp.

As a whole, although there is nothing specially new in this collection of hints, it will be found very useful by those who have charge of horses, because it contains in small compass the little points that need constant attention.

J.P.W.

Der Krieg Oesterreichs in der Adria im Jahre 1866. Seekriegsgeschichtliche Studie, verfasst von Ferdinand Ritter von Attlmayer. Pp. 206. Mittheilungen aus dem Gebriete des Seewesens: Pola, Austria.

This account of the Austrian Naval War in the Adriatic in 1866, constitutes Nos. III and IV of Volume XXV of the *Mittheilnngen aus dem Gebiete des Seewesens*, but is issued as a separate volume and paged independently of the other parts.

The author was a captain on the staff of Vice-Admiral W. von Tegetthoff, and speaks as an eye witness and in the spirit of his commander; moreover, his position gave him the opportunity to hear the plans and operations discussed by those in command, and, with the assistance of his comrades and the archives of both Austria and Italy, he has been able to present a most valuable account of this naval war.

The opening article describes the state of the Austrian navy in the spring of 1866, and the problems required to be solved by it in the approaching war; this is followed by an account of the preparations made by Austria and Italy before the war, and a summary of the events up to the battle of Lissa.

The final chapter is the climax of the work: the naval battle at Lissa, which is described with much spirit and with great care, each new position of the fleets being indicated by a diagram showing the position of each ship at that moment.

In spite of the fact that much of the naval material was old even at that day, many lessons of use to-day are taught by this battle.

The strategy of the war and the tactics of the battle are brought out clearly and intelligently; formations were changed to suit the circumstances; the subordinate commanders showed initiative and independence within the limits demanded by concerted action and unity of command; the disadvantage of excessive fire, resulting in great masses of smoke which obscured the view, and the advantages of deliberate well-aimed fire are clearly set forth; finally the importance of small-arm fire (as exemplified in this battle) is made manifest, and it is evident that it is a factor which must be taken into account.

The book is embelished with photo-gravures, maps and diagrams, and is in every respect a beautiful work.

J.P.W.

BOOK NOTICES.

[These books will be fully *reviewed* as space becomes available.]

Life of Napoleon Bonaparte, by William Milligan Sloane, Ph. D., L. H. D., Professor of History in Princeton University, Volume III. New York: The Century Co.. 1896. Complete in four volumes, cloth, $7.00; half morocco, $8.00; three-quarters morocco, $9.00; full morocco, $12.50.

The Naval Annual, 1897. T. A. Brassey. Portsmouth: J. Griffin & Co., 2, The Hard.

The Life of Nelson, the Embodiment of the Sea Power of Great Britain. Captain A. T. Mahan, D.C.L., L.L.D., U.S. Navy. Two volumes. Boston: Little, Brown & Company.

Historischer Rückblick auf die Verpflegung der Armeen im Felde. II. Lieferung. Oberstlientenant Otto Meixner des Generalstabs-Corps. Wien, 1897. L. W. Seidel & Sohn.

Graphische Logarithmen-Tafeln von Anton Ticky. Wien, 1897. Verlag des Oesterr. Ingenieur-und Architekten-Vereines.

Instruction sur la Mitrailleuse Automatique Hotchkiss. Paris: Imprimerie Chaix, Rue Bergère, 20.

Mitrailleuse Automatique Hotchkiss. Paris: Berger-Levrault & Cie.

Notes on the Platte-Dakota Campaign of 1876. Captain D. E. Pearson, 2nd Cavalry, U.S. Army.

Etude d' un Nouveau Matérial pour l' Artillerie Suisse. III. Canons à tir rapide. Bureau d'Artillerie, Berne, Switzerland, 1897.

Revista de Engenheria Militar, Publicacão mensal. Lisbon, Rua Nova do Almada, 27, 2°.

This new *Journal of Military Engineering* issued its first number in July, 1896, and became at once well known to the military world through its article on the resistance of various substances to the small caliber projectile of the modern infantry arm. The general character of the contents of the number thus far issued is seen from a glance at the quotations in our Index to Current Artillery Literature.

The *Revista* appears monthly in a well printed pamphlet of about fifty pages of the size of our page, and the excellence of its contents gives promise of the successful career we earnestly wish for it. ED.

Die Umschau, edited by Dr. J. H. Bechhold, Frankfurt a. M., Germany.

Die Umschau, a review of the developments in science, literature and art, promises to be a valuable weekly for the general reader as well as for the professional man. Its career begins with the opening of the present year and we greet it with our best wishes for the success of its undertaking.

Among the list of contributors are found such well-known names as Justin McCarthy (English History), Professor Vict. Meyer of Heidelberg (Chemistry), Professor Felix Auerbach (Physics), Professor Freytag (Engineering), etc.

It appears in the form of a pamphlet somewhat smaller than *The Nation*, and containing in each weekly number about twenty pages of printed matter.

ED.

INDEX TO CURRENT ARTILLERY LITERATURE.

PERIODICALS CITED.

Abbreviations employed in index are added here in brackets.

All the periodicals are preserved in the Artillery School Library, Fort Monroe, Virginia.

ENGLAND.

Aldershot Military Society. *Occasional.*
Aldershot. Copies 6*d each.*

Arms and Explosives. [*Arms and Ex.*] *Monthly.*
Effingham House, Arundel Street, Strand, London, W. C. Per year 7*s.*

Army and Navy Gazette. [*A. and N. Gaz.*] *Weekly.*
3 *York Street, Covent Garden, London. Per year* £1 12*s* 6*d.*

Canadian Military Gazette. [*Can. Gaz.*] *Fortnightly.*
Box 2179 *Montreal, Canada. Per year* $2.00.

The Engineer. [*Eng.*] *Weekly.*
33 *Norfolk Street, Strand, London. Per year* £2 6*d.*

Engineering. [*Eng'ing.*] *Weekly.*
35-36 *Bedford Street, Strand, London, W. C. Per year* £2 6*d.*

Journal of the Royal United Service Institution. [*Jour. R. U.S.I.*] *Monthly.*
17 *Great George Street, London, S. W. Per year* 2*s.*

Journal of the United Service Institution of India. [*Jour. U. S. I. India*] *Monthly.*
Simla, India. Per year $2.50.

Photographic Journal. [*Photo. Jour.*] *Monthly.*
12 *Hanover Square, London.*

Proceedings of the Institution of Civil Engineers. [*Proceedings I. C. E.*]
25 *Great George Street, Westminister, London.*

Proceedings of the Institution of Mechanical Engineers.
[*Proceedings I. M. E.*] 19 *Victoria Street, Westminister, London.*

Proceedings of the Royal Artillery Institution. [*Proceedings R. A. I.*] *Monthly.*
Woolwich, England.

Professional Papers of the Corps of Royal Engineers.
[*Prof. Papers Corps Royal Eng'rs.*]
Chatham, England.

Review of Reviews. [*Rev. of Rev. Austral.*] *Monthly.*
169 *Queen Street, Melbourne, Australia. Per year* 11 s. 6 d.

Transactions of the Canadian Institute. [*Trans. Canadian Inst.*]
58 *Richmond Street, Toronto, Canada.*

Transactions of the Canadian Society of Civil Engineers.
[*Trans. Canadian Soc. C. E.*]
Montreal, Canada.

Transactions of the East of Scotland Tactical Society.
[*Trans. E. of S. Tactical Soc.*]
51 *Hanover Street, Edinburgh, Scotland.*

Transactions of the Institute of Naval Architects.
[*Trans. Inst. Naval Architects.*]
5 *Adelphi Terrace, London, W.C.*

United Service Gazette. [*U. S. Gaz.*] *Weekly.*
4-6 *Catherine Street, Strand, London, W. C.* *Per year* £1 10*s* 6*d.*

FRANCE.

L'Avenir Militaire. [*Avenir.*] *Semi-weekly.*
13 *Quai Voltaire, Paris.* *Per year* 18 *Fr.*

Le Génie Civil. [*Génie C.*] *Weekly.*
8 *Rue St. Dominique, Paris.* *Per year* 45 *Fr.*

Journal des Sciences Militaires. [*Sciences Militaires*] *Monthly.*
Rue et Passage Dauphine 30, *Paris.* *Per year* 40 *Fr.*

La Marine Française. [*Marine F.*] *Semi-monthly.*
23 *Rue Madame, Paris.* *Per year* 30 *Fr.*

Mémoires et Compte Rendu des Travaux de la Société des Ingénieurs Civils.
[*Ingénieurs Civils.*] *Monthly.*
10 *Cité Rougemont, Paris.* *Per year* 36 *Fr.*

Mémorial des Poudres et Salpêtres. [*M. Poudres et S.*] *Quarterly.*
Quai des Grands-Augustins, 55, *Paris.* *Per year* 12 *Fr.*

Le Monde Militaire. [*Monde.*] *Fortnightly.*
76 *Rue de Seine, Paris.* *Per year* 6 *Fr.*

Revue d'Artillerie. [*R. Artillerie.*] *Monthly.*
5 *Rue des Beaux-Arts, Paris.* *Per year* 22 *Fr.*

Revue de Cavalerie. [*R. Cav.*] *Monthly.*
Berger Levrault et Cie, Rue des Beaux-Arts 5, *Paris.* *Per year* 33 *Fr.*

Revue du Cercle Militaire. [*Cercle.*] *Weekly.*
37 *Rue de Bellechasse, Paris.* *Per year* 27 *Fr.*

Revue du Génie Militaire. [*Génie M.*] *Monthly.*
8 *Rue Saint-Dominique, Paris.* *Per year* 27 *Fr.*

Revue d'Infanterie. [*R. Inf.*] *Monthly.*
11 *Place Saint André-des-Arts, Paris.* *Per year* 25 *Fr.*

Revue Maritime et Coloniale. [*R. Maritime.*] *Monthly.*
L. Baudoin, Rue et Passage Dauphine 30, *Paris.* *Per year* 56 *Fr.*

Revue Militaire de l'Etranger. [*Etranger.*] *Monthly.*
L. Baudoin, Rue et Passage Dauphine 30, *Paris.* *Per year* 15 *Fr.*

Revue Militaire Universelle. [*R. Univ.*] *Monthly.*
11 *Place Saint André-des-Arts, Paris.* *Per year* 25 *Fr.*

Le Yacht—Journal de la Marine. [*Yacht.*] *Weekly.*
55 *Rue de Chateaudun, Paris.* *Per year* 30 *Fr.*

GERMANY.

Allgemeine Militaer-Zeitung. [*A. M.-Zeitung.*] *Semi-weekly.*
Darmstadt. *Per year* 24 *M.*

Archiv fuer die Artillerie-und Ingenieur Offiziere. [*Archiv.*] *Monthly.*
Koch Strasse, 68-78, *Berlin, S. W.* 12. *Per year* 12 *M.*

Beiheft zum Militaer-Wochenblatt. [*Beiheft.*]
Koch Strasse, 68, *S. W., Berlin.*

Deutsche Heeres-Zeitung. [*Heeres-Zeit.*] *Semi-weekly.*
Wilhelmstrasse 15, *Berlin. Per year* $6.00.

Internationale Revue. [*Int. Revue.*] *Monthly.*
Blasewitzer Strasse 15, *Dresden. Per quarter* 6 *M.*

Jahrbuecher fuer die deutsche Armee und Marine. [*Jahrbuecher.*] *Monthly.*
Mohren Strasse, 19, *Berlin, W.* 8. *Per year* 32 *M.*

Kriegswaffen. [*Kriegswaffen.*] *Monthly.*
Rathenow, Germany. Per year $4.50.

Marine Rundschau. [*Rundschau.*] *Monthly.*
Koch Strasse, 68-70, *Berlin. Per year* 3 *M.*

Militaer-Wochenblatt. [*Wochenblatt.*] *Fortnightly.*
Koch Strasse, 68, *Berlin, S. W.* 12. *Per Year* 20 *M.*

Militärische Rundschau. [*Mil. Rundschau.*] *Monthly.*
Zuckschwerdt & Co., Leipzig. Per quarter 4.75 *M.*

Stahl und Eisen. [*Stahl u. Eisen.*] *Fortnightly.*
Schadenplatz 14, *Düsseldorf. Per year* $5.00.

Umschau, Die [*Umschau.*] *Weekly.*
Frankfort a. M. Per year 10 *M.*

AUSTRIA.

Mittheilungen ueber Gegenstaende des Artillerie und Genie-Wesens.
[*Mitth. Art. u. G.*] *Monthly.*
Wien, VI, Getreidemarkt 9. *Per year* 1 *Fl.* 50 *Kr.*

Mittheilungen aus dem Gebiete des Seewesens. [*Seewesens.*] *Monthly.*
Pola. Per year 14 *M.*

Organ der Militaer Wissenchaftlichen Vereine. [*Vereine.*]
Wien I, Stauchgasse No. 4. *Per year*, 8-14 *numbers*, 6 *Fl.*

Zeitschrift des Oesterreichischen Ingenieur und Architekten Vereines.
[*Z. Architekten Vereines.*] *Weekly.*
I. Eschenbachgasse, No. 9, *Wien. Per year* 10 *Fl.*

SWITZERLAND AND BELGIUM.

Allgemeine Schweizerische Militaer-Zeitung. [*A.S.M. Zeitung.*] *Weekly.*
Basel, Switzerland. Per year, 8 *Fr.*

La Belgique Militaire. [*Belgique M.*] *Weekly.*
Rue St. Georges 32, *Ixelles, Belgium. Per year* 12.50 *Fr.*

Monatschrift fuer Offiziere Aller Waffen. [*Monatschr.*] *Monthly.*
Frauenfeld, Switzerland. Per year 5 *Fr., plus postage.*

Revue de l'Armée Belge. [*A. Belge.*] *Bi-monthly.*
22 *Rue des Guillemins, Liège, Belgium. Per year* 13 *Fr.*

Revue Militaire Suisse. [*R. M. Suisse.*] *Monthly.*
Escalier-du-Marché, Lausanne, Switzerland. Per year 10 *Fr.*

Schweizerische Zeitschrift fuer Artillerie und Genie. [*S. Zeitschrift.*]
Monthly.
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5 *Calle de Cervantes, Barcelona, Spain. Per year* 32 *Fr.*

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Largo de S. Domingos No. 11, *Lisbon, Portugal. Per year U. S.* $6.00.

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56 *Calle de Alcalá, Madrid, Spain. Price U. S.* $4.45.

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262 *Rua da Princeza, Lisbon, Portugal. Per year,* $2.60.

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Copenhagen, Denmark. Per year, U. S., $2.50.

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47 *Cedar Street, New York City. Per year* $3.00.

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American Machinist. [*Amer. Mach.*] *Weekly.*
256 *Broadway, New York City. Per year* $3.00.

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59 *Ninth Street, Pittsburgh, Pa. Per year* $4.00.

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Cassier's Magazine. [*Cas. Mag.*] *Monthly.*
World Building, New York City. Per year $3.00.

Digest of Physical Tests. [*Digest.*] *Quarterly.*
1424 *N. 9th Street, Philadelphia. Per year* $1.00.

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13 *Park Row, New York City. Per Year* $3.00.

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106-108 *Fulton Street, New York City. Per year* $2.50.

Engineering News and American Railroad Journal. [*Eng'ing News and R.R. Jour.*] *Weekly.*
Tribune Building, New York City. Per year $5.00.

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253 *Broadway, New York City. Per year* $5.00.

The Iron Age. [*Iron Age.*] *Weekly.*
96-102 *Reade Street, New York City. Per year* $4.50.

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421 *Market Street, San Francisco, Cal.*

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Easton, Pa. Per year $5.00.

Journal American Society of Naval Engineers. [*A.S.N. Egrs.*] *Quarterly.*
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Journal of the Franklin Institute. [*Frank. Inst.*]
Philadelphia, Pa., Per year $5.00.

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Governor's Island, New York City. Per year $4.00.

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1737 *Monadnock Block, Chicago, Illinois. Per year* $2.00.

Marine Review. [*Mar. Rev.*] *Weekly.*
Cleveland, Ohio. Per year $2.00.

Military Information Division. [*Mil. Information Div.*]
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Pennsylvania Magazine of History and Biography. [*Penn. Mag. of Hist.*] *Quarterly.*
13 *Locust Street, Philadelphia. Per year* $3.00.

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60 *and* 62 *E.* 11*th Street, New York City.. Per year* $5.00.

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Cornell University, Ithaca, New York. Per year $3.00.

Popular Science Monthly. [*Pop. Sc. Mo.*] *Monthly.*
72 *Fifth Avenue, New York City. Per year* $5.00.

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[*Proceedings A.S. Civil Eng'rs*]
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Annapolis, Md. Per year $3.50.

Public Opinion. [*Pub. Opin.*] *Weekly.*
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13 *Astor Place, New York City. Per year* $2.50.

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361 *Broadway, New York City. Per year* $3.00.

Shooting and Fishing. *Weekly.*
293 *Broadway, New York City. Per year* $3.50.

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26 *Cortlandt Street, New York City. Per year* $5.00.

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P. O. Box 225, *New York City.*

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12 *West 31st Street, New York City.*

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The United Service. [*U. Serv.*] *Monthly.*
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Western Electrician. [*West. Elec.*]
510 *Marquette Building, Chicago, Illinois. Per year* $3.00.

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